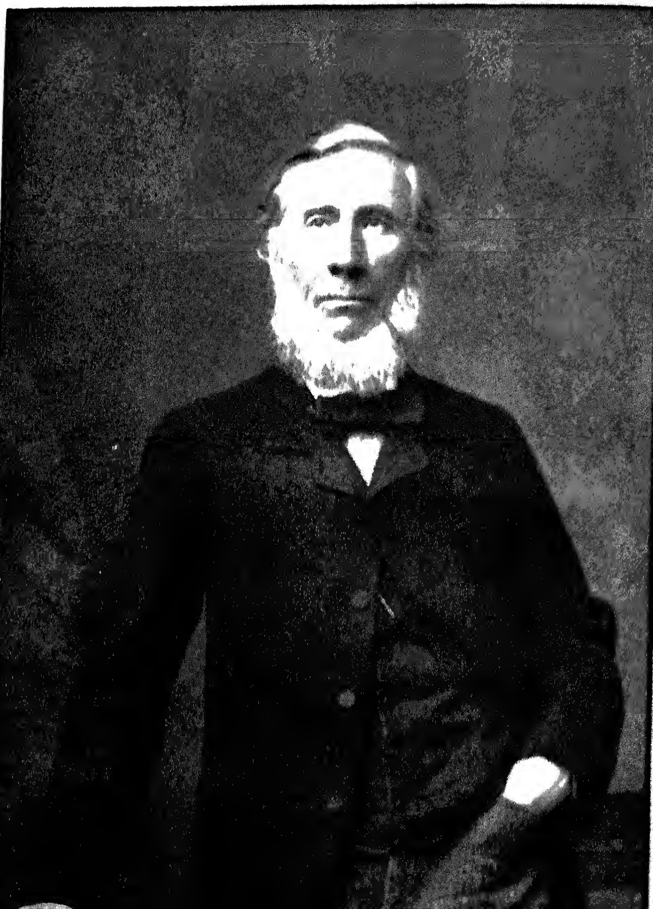

BY

JOHN TYNDALL, F.R.S.

PART TWO

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SCIENCE

CONTENTS

OF

FRAGMENTS OF SCIENCE

VOLUME TWO

FRAGMENTS OF SCIENCE

the bright sky they perceived an illuminator; in the all-encircling
an embracer; in the roar of thunder and in the violence of the storm
e presence of a shouter and of furious strikers; and out of the rain
d an Indra, or giver of rain.—MAX MÜLLER.

I

REFLECTIONS ON PRAYER AND NATURAL LAW

1861

AMID the apparent confusion and caprice of na
phenomena, which roused emotions hostile to
investigation, it must for ages have seemed h
to seek for law or orderly relation; and before
ght of law dawned upon the unfolding human
e otherwise inexplicable effects were referred to
l agency. In the fall of a cataract the savage
leap of a spirit, and the echoed thunder-peal wa
the hammer-clang of an exasperated god. Pro
of these terrible powers was the consequence,
ifice was offered to the demons of earth and ai

). Probably every change from ancient savagery to
esent enlightenment has excited, in a greater or less
ee, fears of this kind. But the fact is, that we h
t yet determined whether its present form is necess
the life and warmth of religious feeling. We may
linking the imperishable with the transitory, and c
nd the living plant with the decaying pole to which
ngs. My object, however, at present is not to arg
t to mark a tendency. We have ceased to propiti
e powers of nature—ceased even to pray for things
nifest contradiction to natural laws. In Protest
untries, at least, I think it is conceded that the
miracles is past.

At an auberge near the foot of the Rhone glacier
t, in the summer of 1858, an athletic young pri
o, after a solid breakfast, including a bottle of wi
ormed me that he had come up to "bless the mo
ns." This was the annual custom of the place. Y
year the Highest was entreated, by official intercess
make such meteorological arrangements as should
e food and shelter for the flocks and herds of
laisians. A diversion of the Rhone, or a deepening
e river's bed, would, at the time I now mention, h
en of incalculable benefit to the inhabitants of the v
r. But the priest would have shrunk from the idea
king the Omnipotent to open a new channel for
er, or to cause a portion of it to flow over the Grim

us, and we look with suspicion and dislik
losophy, the apparent tendency of which i
up. Probably every change from ancient s
present enlightenment has excited, in a grea
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nds of the natural and non-miraculous. A Prote
leman who was present at the time smiled at thi
. He had no faith in the priest's blessing; stil
ned his prayer different in kind from a re
pen a new river-cut, or to cause the water to
ill.

n a similar manner the same Protestant gentl
ld doubtless smile at the honest Tyrolese priest,
n he feared the bursting of a glacier dam, offere
ifice of the Mass upon the ice as a means of ave
calamity. That poor man did not expect to co
ice into adamant, or to strengthen its texture,
nable it to withstand the pressure of the water;
he expect that his sacrifice would cause the strea
back upon its source and relieve him, by a mi
s presence. But beyond the boundaries of his k
lay a region where rain was generated, he knew
. He was not so presumptuous as to expect a
but he firmly believed that in yonder cloud-land
could be so arranged, without trespass on the mi
, that the stream which threatened him and his p
ld be caused to shrink within its proper bounds.
Both these priests fashioned that which they di

them went mad in the pursuit of this obj
in such a consummation, involving, as it
personal profit to the inventor, was extre
and every attempt to destroy this faith was
resentment on the part of those who held
however, as men became more and more a
the true functions of machinery, the dre
The hope of getting work out of mere me
binations disappeared: but still there rem
speculator a cloud-land denser than that w
imagination of the Tyrolese priest, and ou
still hoped to evolve perpetual motion. 'T
mystic store of chemic force, which nobod
there were heat and light, electricity and m
competent to produce mechanical motion.'
was the mine in which our gem must be sou
ified and more refined form of the ancient
and, for aught I know, a remnant of sangu
may at the present moment be engaged on
which like-minded men in former ages left

And why should a perpetual motion, eve
ern conditions, be impossible? The answer
tion is the statement of that great generalizat
science, which is known under the name of

from heaven, or deflect toward us a single beam of the sun. Those, therefore, who believe that the miraculous is still active in nature, may, with perfect consistency, join in our periodic prayers for fair weather and for rain: while those who hold that the age of miracles is past will, if they be consistent, refuse to join in these petitions. And these latter, if they wish to fall back upon such a justification, may fairly urge that the latest conclusions of science are in perfect accordance with the doctrine of the Master Himself, which manifestly was that the distribution of natural phenomena is not affected by moral or religious causes. "He maketh His sun to rise on the evil and on the good, and sendeth rain on the just and on the unjust." Granting "the power of Free Will in man," so strongly claimed by Professor Mansel in his admirable defence of the belief in miracles, and assuming the efficacy of free prayer to produce changes in external nature, it necessarily follows that natural laws are more or less at the mercy of man's volition, and no conclusion founded on the assumed permanence of those laws would be worthy of confidence.

It is a wholesome sign for England that she numbers among her clergy men wise enough to understand all this, and courageous enough to act up to their knowledge. Such men do service to public character, by encouraging a manly and intelligent conflict with the real causes of disease and scarcity, instead of a delusive reliance on supernatural aid. But they have also a value beyond this local and temporary one. They prepare the public mind for changes which, though inevitable, could hardly, without such preparation, be wrought without violence. Iron is strong; still, water in crystallizing will shiver an iron

envelope, and the more unyielding the metal is, the worse for its safety. There are in the world men who would encompass philosophic speculation by a rigid envelope, hoping thereby to restrain it, but in reality giving it explosive force. In England, thanks to men of the stamp to which I have alluded, scope is gradually given to thought for changes of aggregation, and the envelope slowly alters its form, in accordance with the necessities of the time.

The proximate origin of the foregoing slight article, and probably the remoter origin of the next following one, was this. Some years ago, a day of prayer and humiliation, on account of a bad harvest, was appointed by the proper religious authorities; but certain clergymen of the Church of England, doubting the wisdom of the demonstration, declined to join in the services of the day. For this act of nonconformity they were severely censured by some of their brethren. Rightly or wrongly, my sympathies were on the side of these men; and, to lend them a helping hand in their struggle against odds, I inserted the foregoing chapter in a little book entitled "Mountaineering in 1861." Some time subsequently I received from a gentleman of great weight and distinction in the scientific world, and, I believe, of perfect orthodoxy in the religious one, a note directing my attention to an exceedingly thoughtful article on Prayer and Cholera in the "Pall Mall Gazette." My eminent correspondent deemed the article a fair answer to the remarks made by me in 1861. I, also, was struck by the temper and ability of the article, but I could not deem its arguments satisfactory, and in a short note to the editor of the "Pall Mall Gazette" I ventured to state so much. This letter elicited some very able replies, and a second leading article was also devoted to the subject. In answer to all, I risked the publication of a second letter, and soon afterward, by an extremely courteous note from the editor, the discussion was closed.

Though thus stopped locally, the discussion flowed in other directions. Sermons were preached, essays were published, articles were written, while a copious correspondence occupied the pages of some of the religious newspapers. It gave me sincere pleasure to notice that the discussion, save in a few cases where natural coarseness had the upper hand, was conducted with a minimum of vituperation. The severity shown was hardly more than sufficient to demonstrate earnestness, while gentlemanly feeling was too predominant to permit that earnestness to contract itself to bigotry or to clothe itself in abuse. It was probably the memory of this discussion which caused another excellent friend of mine to recommend to my perusal the exceedingly able work which in the next article I have endeavored to review.

Mr. Mozley's book belongs to that class of writing of which Butler may be taken as the type. It is strong, genuine argument about difficult matters, fairly tracing what *is* difficult, fairly trying to grapple, not with what appears the gist and strong point of a question, but with what really at bottom is the knot of it. It is a book the reasoning of which may not satisfy every one. . . . But we think it is a book for people who wish to see a great subject handled on a scale which befits it, and with a perception of its real elements. It is a book which will have attractions for those who like to see a powerful mind applying itself, without shrinking or holding back, without trick or reserve or show of any kind, as a wrestler closes body to body with his antagonist, to the strength of an adverse and powerful argument.—TIMES, *Tuesday, June 5*, 1866.

We should add, that the faults of the work are wholly on the surface and in the arrangement; that the matter is as solid and as logical as that of any book within recent memory, and that it abounds in striking passages, of which we have scarcely been able even to give a sample. No future arguer against miracles can afford to pass it over.—SATURDAY REVIEW, *September* 15, 1866.

II

MIRACLES AND SPECIAL PROVIDENCES[1]

1867

IT is my privilege to enjoy the friendship of a select number of religious men, with whom I converse frankly upon theological subjects, expressing without disguise the notions and opinions I entertain regarding their tenets, and hearing in return these notions and opinions subjected to criticism. I have thus far found them liberal and loving men, patient in hearing, tolerant in reply, who know how to reconcile the duties of courtesy with the earnestness of debate. From one of these, nearly a year ago, I received a note, recommending strongly to my attention the volume of "Bampton Lectures" for 1865,

[1] "Fortnightly Review," New Series, vol. i. p. 645.

Previous to receiving this note, I had in part made the acquaintance of the work through an able and elaborate review of it in the "Times." The combined effect of the letter and the review was to make the book the companion of my summer tour in the Alps. There, during the wet and snowy days which were only too prevalent in 1866, and during the days of rest interpolated between days of toil, I made myself more thoroughly conversant with Mr. Mozley's volume. I found it clear and strong—an intellectual tonic, as bracing and pleasant to my mind as the keen air of the mountains was to my body. From time to time I jotted down thoughts regarding it, intending afterward to work them up into a coherent whole. Other duties, however, interfered with the complete carrying out of this intention, and what I wrote last summer I now publish, not hoping to be able, within any reasonable time, to render my defence of scientific method more complete.

Mr. Mozley refers at the outset of his task to the movement against miracles which of late years has taken place, and which determined his choice of a subject. He acquits modern science of having had any great share in the production of this movement. The objection against miracles, he says, does not arise from any minute knowledge of the laws of nature, but simply because they are opposed to that plain and obvious order of nature which everybody sees. The present movement is, he thinks, to be ascribed to the greater earnestness and penetration of the present age. Formerly miracles were accepted without question, because without reflection; but the exercise of the "historic imagination" is a characteristic of our own time. Men are now accustomed to place before themselves vivid

images of historic facts; and when a miracle rises to view, they halt before the astounding occurrence, and, realizing it with the same clearness as if it were now passing before their eyes, they ask themselves, "Can this have taken place?" In some instances the effort to answer this question has led to a disbelief in miracles, in others to a strengthening of belief. The aim of Mr. Mozley's lectures is to show that the strengthening of belief is the logical result which ought to follow from the examination of the facts.

Attempts have been made by religious men to bring the Scripture miracles within the scope of the order of nature, but all such attempts are rejected by Mr. Mozley as utterly futile and wide of the mark. Regarding miracles as a necessary accompaniment of a revelation, their evidential value in his eyes depends entirely upon their deviation from the order of nature. Thus deviating, they suggest and illustrate a power higher than nature, a "personal will"; and they commend the person in whom this power is vested as a messenger from on high. Without these credentials such a messenger would have no right to demand belief, even were his assertions regarding his Divine mission backed by a holy life. Nor is it by miracles alone that the order of nature is, or may be, disturbed. The material universe is also the arena of "special providences." Under these two heads Mr. Mozley distributes the total preternatural. One form of the preternatural may shade into the other, as one color passes into another in the rainbow; but, while the line which divides the specially providential from the miraculous cannot be sharply drawn, their distinction broadly expressed is this: that, while a special providence can only excite surmise more or less probable, it is "the nature of a mir-

acle to give proof, as distinguished from mere surmise, of Divine design."

Mr. Mozley adduces various illustrations of what he regards to be special providences, as distinguished from miracles. "The death of Arius," he says, "was not miraculous, because the coincidence of the death of a heresiarch taking place when it was peculiarly advantageous to the orthodox faith . . . was not such as to compel the inference of extraordinary Divine agency; but it was a special providence, because it carried a reasonable appearance of it. The miracle of the Thundering Legion was a special providence, but not a miracle, for the same reason, because the coincidence of an instantaneous fall of rain, in answer to prayer, carried some appearance, but not proof, of preternatural agency." The eminent lecturer's remarks on this head brought to my recollection certain narratives published in Methodist magazines, which I used to read with avidity when a boy. The general title of these exciting stories, if I remember right, was "The Providence of God Asserted," and in them the most extraordinary escapes from peril were recounted and ascribed to prayer, while equally wonderful instances of calamity were adduced as illustrations of Divine retribution. In such magazines, or elsewhere, I found recorded the case of the celebrated Samuel Hick, which, as it illustrates a whole class of special providences approaching in conclusiveness to miracles, is worthy of mention here. It is related of this holy man that, on one occasion, flour was lacking to make the sacramental bread. Grain was present, and a windmill was present, but there was no wind to grind the corn. With faith undoubting, Samuel Hick prayed to the Lord of the winds: the sails turned, the

corn was ground, after which the wind ceased. According to the canon of the Bampton Lecturer, this, though carrying a strong appearance of an immediate exertion of Divine energy, lacks by a hair-breadth the quality of a miracle. For the wind *might* have arisen, and might have ceased, in the ordinary course of nature. Hence the occurrence did not "compel the inference of extraordinary Divine agency." In like manner Mr. Mozley considers that "the appearance of the cross to Constantine was a miracle, or a special providence, according to which account of it we adopt. As only a meteoric appearance in the shape of a cross it gave some token of preternatural agency, but not full evidence."

In the Catholic canton of Switzerland where I now write, and still more among the pious Tyrolese, the mountains are dotted with shrines, containing offerings of all kinds, in acknowledgment of special mercies. Legs, feet, arms, and hands—of gold, silver, brass, and wood, according as worldly possessions enabled the grateful heart to express its indebtedness. Most of these offerings are made to the Virgin Mary. They are recognitions of "special providences," wrought through the instrumentality of the Mother of God. Mr. Mozley's belief, that of the Methodist chronicler, and that of the Tyrolese peasant, are substantially the same. Each of them assumes that nature, instead of flowing ever onward in the uninterrupted rhythm of cause and effect, is mediately ruled by the free human will. As regards *direct* action upon natural phenomena, man's wish and will, as expressed in prayer, are confessedly powerless; but prayer is the trigger which liberates the Divine power, and to this extent, if the will be free, man, of course, commands nature.

Did the existence of this belief depend solely upon he material benefits derived from it, it could not, in my pinion, last a decade. As a purely objective fact, we hould soon see that the distribution of natural phenomna is unaffected by the merits or the demerits of men; hat the law of gravitation crushes the simple worshippers f Ottery St. Mary, while singing their hymns, just as urely as if they were engaged in a midnight brawl. The old of this belief upon the human mind is not due to utward verification, but to the inner warmth, force, and levation with which it is commonly associated. It is lain, however, that these feelings may exist under the nost various forms. They are not limited to Church of England Protestantism—they are not even limited to Christianity. Though less refined, they are certainly not ess strong in the heart of the Methodist and the Tyrolese easant than in the heart of Mr. Mozley. Indeed, those eelings belong to the primal powers of man's nature. A 'sceptic'' may have them. They find vent in the battlery of the Moslem. They take hue and form in the hunting-grounds of the Red Indian; and raise all of them, as hey raise the Christian, upon a wave of victory, above he terrors of the grave.

The character, then, of a miracle, as distinguished from special providence, is that the former furnishes *proof*, vhile in the case of the latter we have only surmise. Dissolve the element of doubt, and the alleged fact passes rom the one class of the preternatural into the other. In ther words, if a special providence could be proved to e a special providence, it would cease to be a special providence and become a miracle. There is not the least loudiness about Mr. Mozley's meaning here. A special

providence is a doubtful miracle. Why, then, not call it so? The term employed by Mr. Mozley conveys no negative suggestion, whereas the negation of certainty is the peculiar characteristic of the thing intended to be expressed. There is an apparent unwillingness on the part of the lecturer to call a special providence what his own definition makes it to be. Instead of speaking of it as a doubtful miracle, he calls it "an invisible miracle." He speaks of the point of contact of supernatural power with the chain of causation being so high up as to be wholly, or in part, out of sight, whereas the essence of a special providence is the uncertainty whether there is any contact at all, either high or low. By the use of an incorrect term, however, a grave danger is avoided. For the idea of doubt, if kept systematically before the mind, would soon be fatal to the special providence, considered as a means of edification. The term employed, on the contrary, invites and encourages the trust which is necessary to supplement the evidence.

This inner trust, though at first rejected by Mr. Mozley in favor of external proof, is subsequently called upon to do momentous duty in regard to miracles. Whenever the evidence of the miraculous seems incommensurate with the fact which it has to establish, or rather when the fact is so amazing that hardly any evidence is sufficient to establish it, Mr. Mozley invokes "the affections." They must urge the reason to accept the conclusion, from which unaided it recoils. The affections and emotions are eminently the court of appeal in matters of real religion, which is an affair of the heart; but they are not, I submit, the court in which to weigh allegations regarding the credibility of physical facts. These must be judged by

the dry light of the intellect alone, appeals to the affections being reserved for cases where moral elevation, and not historic conviction, is the aim. It is, moreover, because the result, in the case under consideration, is deemed desirable that the affections are called upon to back it. If undesirable, they would, with equal right, be called upon to act the other way. Even to the disciplined scientific mind this would be a dangerous doctrine. A favorite theory—the desire to establish or avoid a certain result—can so warp the mind as to destroy its powers of estimating facts. I have known men to work for years under a fascination of this kind, unable to extricate themselves from its fatal influence. They had certain data, but not, as it happened, enough. By a process exactly analogous to that invoked by Mr. Mozley, they supplemented the data, and went wrong. From that hour their intellects were so blinded to the perception of adverse phenomena that they never reached truth. If, then, to the disciplined scientific mind, this incongruous mixture of proof and trust be fraught with danger, what must it be to the indiscriminate audience which Mr. Mozley addresses? In calling upon this agency he acts the part of Frankenstein. It is a monster thus evoked that we see stalking abroad, in the degrading spiritualistic phenomena of the present day. Again, I say, where the aim is to elevate the mind, to quicken the moral sense, to kindle the fire of religion in the soul, let the affections by all means be invoked; but they must not be permitted to color our reports, or to influence our acceptance of reports of occurrences in external nature. Testimony as to natural facts is worthless when wrapped in this atmosphere of the affections; the most earnest subjective truth

being thus rendered perfectly compatible with the most astounding objective error.

There are questions in judging of which the affections or sympathies are often our best guides, the estimation of moral goodness being one of these. But at this precise point, where they are really of use, Mr. Mozley excludes the affections and demands a miracle as a certificate of character. He will not accept any other evidence of the perfect goodness of Christ. "No outward life and conduct," he says, "however irreproachable, could prove His perfect sinlessness, because goodness depends upon the inward motive, and the perfection of the inward motive is not proved by the outward act." But surely the miracle is an outward act, and to pass from it to the inner motive imposes a greater strain upon logic than that involved in our ordinary methods of estimating men. There is, at least, moral congruity between the outward goodness and the inner life, but there is no such congruity between the miracle and the life within. The test of moral goodness laid down by Mr. Mozley is not the test of John, who says, "He that doeth righteousness is righteous"; nor is it the test of Jesus: "By their fruits ye shall know them: do men gather grapes of thorns, or figs of thistles?" But it *is* the test of another: "If thou be the Son of God, command that these stones be made bread." For my own part, I prefer the attitude of Fichte to that of Mr. Mozley. "The Jesus of John," says this noble and mighty thinker, "knows no other God than the True God, in whom we all are, and live, and may be blessed, and out of whom there is only Death and Nothingness. And," continues Fichte, "he appeals, and rightly appeals, in support of this truth, not to reasoning, but to

such works as no other man did, he ought, logically speaking, to accept the works of those who, in His name, had cast out devils, as demonstrating a proportionate goodness on their part. But it is people of this class who are consigned to everlasting fire prepared for the devil and his angels. Such zeal as that of Mr. Mozley for miracles tends, I fear, to eat his religion up. The [illegible] to stifle the spiritual. The truly religious soul needs no miraculous proof of the goodness of Christ. The words addressed to Matthew at the receipt of custom required no miracle to produce obedience. It was by no exercise of the supernatural that Jesus caused those sent to seize Him to go backward and fall to the ground. It was the sublime and holy effluence from within, which needed no prodigy to command it to the reverence even of his foes.

As regards the function of miracles in the founding of a religion, Mr. Mozley institutes a comparison between the religion of Christ and that of Mahomet; and he [illegible] the latter as "irrational" because it does not pretend to adduce miracles in proof of its supernatural origin. But the religion of Mahomet, notwithstanding [illegible], has thriven in the world, and at one time it held sway over larger populations than Christianity itself. The spread and influence of Christianity are, however, brought forward by Mr. Mozley as "a permanent, [illegible] and incalculable practical result" of Christian miracles, and he makes use of this result to strengthen his plea for the miraculous. His logical warrant for this proceeding is not clear. It is the method of science, when a phenomenon presents itself, toward the production of which several elements may contribute, to exclude them one by one, so as to arrive at length at the truly [illegible]

cause. Heat, for example, is associated with a phenomenon; we exclude heat, but the phenomenon remains: hence, heat is not its cause. Magnetism is associated with a phenomenon; we exclude magnetism, but the phenomenon remains: hence, magnetism is not its cause. Thus, also, when we seek the cause of a diffusion of a religion—whether it be due to miracles, or to the spiritual force of its founders—we exclude the miracles, and, finding the result unchanged, we infer that miracles are not the effective cause. This important experiment Mohammedanism has made for us. It has lived and spread without miracles; and to assert, in the face of this, that Christianity has spread *because* of miracles, is, I submit, opposed both to the spirit of science and the common-sense of mankind.

The incongruity of inferring moral goodness from miraculous power has been dwelt upon above; in another particular also the strain put by Mr. Mozley upon miracles is, I think, more than they can bear. In consistency with his principles, it is difficult to see how he is to draw from the miracles of Christ any certain conclusion as to His Divine nature. He dwells very forcibly on what he calls "the argument from experience," in the demolition of which he takes obvious delight. He destroys the argument, and repeats it, for the mere pleasure of again and again knocking the breath out of it. Experience, he urges, can only deal with the past; and the moment we attempt to project experience a hair-breadth beyond the point it has at any moment reached, we are condemned by reason. It appears to me that when he infers from Christ's miracles a Divine and altogether superhuman energy, Mr. Mozley places himself

precisely under this condemnation. For what is his logical ground for concluding that the miracles of the New Testament illustrate Divine power? May they not be the result of expanded human power? A miracle he defines as something impossible to man. But how does he know that the miracles of the New Testament are impossible to man? Seek as he may, he has absolutely no reason to adduce save this—that man has never hitherto accomplished such things. But does the fact that man *has* never raised the dead prove that he *can* never raise the dead? "Assuredly not," must be Mr. Mozley's reply; "for this would be pushing experience beyond the limit it has now reached—which I pronounce unlawful." Then, a period may come when man will be able to raise the dead. If this be conceded—and I do not see how Mr. Mozley can avoid the concession—it destroys the necessity of inferring Christ's Divinity from His miracles. He, it may be contended, antedated the humanity of the future; as a mighty tidal wave leaves high upon the beach a mark which by and by becomes the general level of the ocean. Turn the matter as you will, no other warrant will be found for the all-important conclusion that Christ's miracles demonstrate Divine power, than an argument which has been stigmatized by Mr. Mozley as a "rope of sand"—the argument from experience.

The learned Bampton Lecturer would be in this position, even had he seen with his own eyes every miracle recorded in the New Testament. But he has *not* seen these miracles; and his intellectual plight is therefore worse. He accepts these miracles on testimony. Why does he believe that testimony? How does he know that

it is not delusion; how is he sure that it is not even fraud? He will answer that the writing bears the marks of sobriety and truth; and that in many cases the bearers of this message to mankind sealed it with their blood. Granted with all my heart; but whence the value of all this? Is it not solely derived from the fact that men, *as we know them*, do not sacrifice their lives in the attestation of that which they know to be untrue? Does not the entire value of the testimony of the Apostles depend ultimately upon our experience of human nature? It appears, then, that those said to have seen the miracles based their inferences from what they saw on the argument from experience; and that Mr. Mozley bases his belief in their testimony on the same argument. The weakness of his conclusion is quadrupled by this double insertion of a principle of belief, to which he flatly denies rationality. His reasoning, in fact, cuts two ways—if it destroys our trust in the order of nature, it far more effectually abolishes the basis on which Mr. Mozley seeks to found the Christian religion.

Over this argument from experience, which at bottom is *his* argument, Mr. Mozley rides rough-shod. There is a dash of scorn in the energy with which he tramples on it. Probably some previous writer had made too much of it, and thus invited his powerful assault. Finding the difficulty of belief in miracles to rise from their being in contradiction to the order of nature, he sets himself to examine the grounds of our belief in that order. With a vigor of logic rarely equalled, and with a confidence in its conclusions never surpassed, he disposes of this belief in a manner calculated to startle those who, with-

out due examination, had come to the conclusion that the order of nature was secure.

What we mean, he says, by our belief in the order of nature, is the belief that the future will be like the past. There is not, according to Mr. Mozley, the slightest rational basis for this belief.

> "That any cause in nature is more permanent than its existing and known effects, extending further, and about to produce other and more instances besides what it has produced already, we have no evidence. Let us imagine," he continues, "the occurrence of a particular physical phenomenon for the first time. Upon that single occurrence we should have but the very faintest expectation of another. If it did occur again, once or twice, so far from counting on another occurrence, a cessation would occur as the most natural event to us. But let it continue one hundred times, and we should find no hesitation in inviting persons from a distance to see it; and if it occurred every day for years, its occurrence would be a certainty to us, its cessation a marvel. What ground of reason can we assign for an expectation that any part of the course of nature will be the next moment what it has been up to this moment, *i.e.* for our belief in the uniformity of nature? None. No demonstrative reason can be given, for the contrary to the recurrence of a fact of nature is no contradiction. No probable reason can be given; for all probable reasoning respecting the course of nature is founded *upon* this presumption of likeness, and therefore cannot be the foundation of it. No reason can be given for this belief. It is without a reason. It rests upon no rational grounds, and can be traced to no rational principle."

"Everything," Mr. Mozley, however, adds, "depends upon this belief, every provision we make for the future, every safeguard and caution we employ against it, all calculation, all adjustment of means to ends, supposes this belief; and yet this belief has no more producible reason for it than a speculation of fancy. . . . It is necessary, all-important for the purposes of life, but solely practical, and possesses no intellectual character. . . . The proper function," continues Mr. Mozley, "of the inductive principle, the argument from experience, the belief in the order of nature—by whatever phrase we designate the same

instinct—is to operate as a practical basis for the affairs of life and the carrying on of human society." To sum up, the belief in the order of nature is general, but it is "an unintelligent impulse, of which we can give no rational account." It is inserted into our constitution solely to induce us to till our fields, to raise our winter fuel, and thus to meet the future on the perfectly gratuitous supposition that it will be like the past.

"Thus, step by step," says Mr. Mozley, with the emphasis of a man who feels his position to be a strong one, "has philosophy loosened the connection of the order of nature with the ground of reason, befriending in exact proportion as it has done this the principle of miracles." For "this belief not having itself a foundation in reason, the ground is gone upon which it could be maintained that miracles, as opposed to the order of nature, are opposed to reason." When we regard this belief in connection with science, "in which connection it receives a more imposing name, and is called the inductive principle," the result is the same. "The inductive principle is only this unreasoning impulse applied to a scientifically ascertained fact. . . . Science has led up to the fact; but there it stops, and for converting this fact into a law, a totally unscientific principle comes into play, the same as that which generalizes the commonest observation of nature."

The eloquent pleader of the cause of miracles passes over without a word the *results* of scientific investigation, as proving anything rational regarding the principles or method by which such results have been achieved. Here, as elsewhere, he declines the test, "By their fruits shall ye know them." Perhaps our best way of proceeding will be to give one or two examples of the mode in which men

of science apply the unintelligent impulse with which Mr. Mozley credits them, and which shall show, by illustration, the surreptitious method whereby they climb from the region of facts to that of laws.

Before the sixteenth century it was known that water rose in a pump; the effect being then explained by the maxim that "Nature abhors a vacuum." It was not known that there was any limit to the height to which the water would ascend, until, on one occasion, the gardeners of Florence, while attempting to raise water to a very great elevation, found that the column ceased at a height of thirty-two feet. Beyond this all the skill of the pump-maker could not get it to rise. The fact was brought to the notice of Galileo, and he, soured by a world which had not treated his science over-kindly, is said to have twitted the philosophy of the time by remarking that Nature evidently abhorred a vacuum only to a height of thirty-two feet. Galileo, however, did not solve the problem. It was taken up by his pupil Torricelli, to whom, after due pondering, the thought occurred, that the water might be forced into the tube by a pressure applied to the surface of the liquid outside. But where, under the actual circumstances, was such a pressure to be found? After much reflection, it flashed upon Torricelli that the atmosphere might possibly exert this pressure; that the impalpable air might possess weight, and that a column of water thirty-two feet high might be of the exact weight necessary to hold the pressure of the atmosphere in equilibrium.

There is much in this process of pondering and its results which it is impossible to analyze. It is by a kind of inspiration that we rise from the wise and sedulous contemplation of facts to the principles on which they

be the weight of the air overhead. He caused a friend to ascend the Puy de Dôme, carrying with him a barometric column; and it was found that during the ascent the column sank, and that during the subsequent descent the column rose.

Between the time here referred to and the present, millions of experiments have been made upon this subject. Every village pump is an apparatus for such experiments. In thousands of instances, moreover, pumps have refused to work; but on examination it has infallibly been found that the well was dry, that the pump required priming, or that some other defect in the apparatus accounted for the anomalous action. In every case of the kind the skill of the pump-maker has been found to be the true remedy. In no case has the pressure of the atmosphere ceased; constancy, as regards the lifting of pump water, has been hitherto the demonstrated rule of nature. So also as regards Pascal's experiment. His experience has been the universal experience ever since. Men have climbed mountains, and gone up in balloons; but no deviation from Pascal's result has ever been observed. Barometers, like pumps, have refused to act; but instead of indicating any suspension of the operations of Nature, or any interference on the part of its Author with atmospheric pressure, examination has in every instance fixed the anomaly upon the instruments themselves. It is this welding, then, of rigid logic to verifying fact that Mr. Mozley refers to an unreasoning impulse."

Let us now briefly consider the case of Newton. Before his time men had occupied themselves with the problem of the solar system. Kepler had deduced, from a vast mass of observations, those general expressions of

planetary motion known as "Kepler's laws." It had been observed that a magnet attracts iron; and by one of those flashes of inspiration which reveal to the human mind the vast in the minute, the general in the particular, it had been inferred that the force by which bodies fall to the earth might also be an attraction. Newton pondered all these things. He looked, as was his wont, into the darkness until it became entirely luminous. How this light arises we cannot explain; but, as a matter of fact, it does arise. Let me remark here that this kind of pondering is a process with which the ancients could have been but imperfectly acquainted. They, for the most part, found the exercise of fantasy more pleasant than careful observation, and subsequent brooding over facts. Hence it is that when those whose education has been derived from the ancients speak of "the reason of man," they are apt to omit from their conception of reason one of its most important factors. Well, Newton slowly marshalled his thoughts, or rather they came to him while he "intended his mind," rising like a series of intellectual births out of chaos. He made this idea of attraction his own. But, to apply the idea to the solar system, it was necessary to know the magnitude of the attraction, and the law of its variation with the distance. His conceptions first of all passed from the action of the earth as a whole to that of its constituent particles. And persistent thought brought more and more clearly out the final conclusion that every particle of matter attracts every other particle with a force varying inversely as the square of the distance between the particles.

Here we have the flower and outcome of Newton's induction; and how to verify it, or to disprove it, was

the next question. The first step of the philosopher in this direction was to prove, mathematically, that if this law of attraction be the true one; if the earth be constituted of particles which obey this law; then the action of a sphere equal to the earth in size on a body outside of it is the same as that which would be exerted if the whole mass of the sphere were contracted to a point at its centre. Practically speaking, then, the centre of the earth is the point from which distances must be measured to bodies attracted by the earth.

From experiments executed before his time, Newton knew the amount of the earth's attraction at the earth's surface, or at a distance of 4,000 miles from its centre. His object now was to measure the attraction at a greater distance, and thus to determine the law of its diminution. But how was he to find a body at a sufficient distance? He had no balloon? and even if he had, he knew that any height to which he could attain would be too small to enable him to solve his problem. What did he do? He fixed his thoughts upon the moon; a body 240,000 miles, or sixty times the earth's radius, from the earth's centre. He virtually weighed the moon, and found that weight to be $\frac{1}{3600}$th of what it would be at the earth's surface. This is exactly what his theory required. I will not dwell here upon the pause of Newton after his first calculations, or speak of his self-denial in withholding them because they did not quite agree with the observations then at his command. Newton's action in this matter is the normal action of the scientific mind. If it were otherwise—if scientific men were not accustomed to demand verification—if they were satisfied with the imperfect while the perfect is attainable, their science,

this succession, besides being permanent, is, under the circumstances, *necessary*; that the gravitating force exerted between the sun and a revolving sphere with an axis inclined to the plane of its orbit, must produce the observed succession of the seasons. Not until this relation between forces and phenomena has been established is the law of reason rendered concentric with the law of nature; and not until this is effected does the mind of the scientific philosopher rest in peace.

The expectation of likeness, then, in the procession of phenomena, is not that on which the scientific mind founds its belief in the order of nature. If the force be *permanent* the phenomena are *necessary*, whether they resemble or do not resemble anything that has gone before. Hence, in judging of the order of nature, our inquiries eventually relate to the permanence of force. From Galileo to Newton, from Newton to our own time, eager eyes have been scanning the heavens, and clear heads have been pondering the phenomena of the solar system. The same eyes and minds have been also observing, experimenting, and reflecting on the action of gravity at the surface of the earth. Nothing has occurred to indicate that the operation of the law has for a moment been suspended; nothing has ever intimated that nature has been crossed by spontaneous action, or that a state of things at any time existed which could not be rigorously deduced from the preceding state.

Given the distribution of matter, and the forces in operation, in the time of Galileo, the competent mathematician of that day could predict what is now occurring in our own. We calculate eclipses in advance, and find our calculations true to the second. We determine

the dates of those that have occurred in the early times of history, and find calculation and history in harmony. Anomalies and perturbations in the planets have been over and over again observed; but these, instead of demonstrating any inconstancy on the part of natural law, have invariably been reduced to consequences of that law. Instead of referring the perturbations of Uranus to any interference on the part of the Author of nature with the law of gravitation, the question which the astronomer proposed to himself was, "How, in accordance with this law, can the perturbation be produced?" Guided by a principle, he was enabled to fix the point of space in which, if a mass of matter were placed, the observed perturbations would follow. We know the result. The practical astronomer turned his telescope toward the region which the intellect of the theoretic astronomer had already explored, and the planet now named Neptune was found in its predicted place. A very respectable outcome, it will be admitted, of an impulse which "rests upon no rational grounds, and can be traced to no rational principle"; which possesses "no intellectual character"; which "philosophy" has uprooted from "the ground of reason," and fixed in that "large irrational department" discovered, for it, by Mr. Mozley, in the hitherto unexplored wilderness of the human mind.

The proper function of the inductive principle, or the belief in the order of nature, says Mr. Mozley, is "to act as a practical basis for the affairs of life, and the carrying on of human society." But what, it may be asked, has the planet Neptune, or the belts of Jupiter, or the whiteness about the poles of Mars, to do with the affairs of society? How is society affected by the fact that the

sun's atmosphere contains sodium, or that the nebula of Orion contains hydrogen gas? Nineteen-twentieths of the force employed in the exercise of the inductive principle, which, reiterates Mr. Mozley, is "purely practical," have been expended upon subjects as unpractical as these. What practical interest has society in the fact that the spots on the sun have a decennial period, and that when a magnet is closely watched for half a century it is found to perform small motions which synchronise with the appearance and disappearance of the solar spots? And yet, I doubt not, Sir Edward Sabine would deem a life of intellectual toil amply rewarded by being privileged to solve, at its close, these infinitesimal motions.

The inductive principle is founded in man's desire to know—a desire arising from his position among phenomena which are reducible to order by his intellect. The material universe is the complement of the intellect, and, without the study of its laws, reason could never have awakened to the higher forms of self-consciousness at all. It is the Non-ego through and by which the Ego is endowed with self-discernment. We hold it to be an exercise of reason to explore the meaning of a universe to which we stand in this relation, and the work we have accomplished is the proper commentary on the methods we have pursued. Before these methods were adopted the unbridled imagination roamed through nature, putting in the place of law the figments of superstitious dread. For thousands of years witchcraft, and magic, and miracles, and special providences, and Mr. Mozley's "distinctive reason of man," had the world to themselves. They made worse than nothing of it—*worse*, I say, because they let and hindered those who might have made

omething of it. Hence it is that, during a single life-me of this era of "unintelligent impulse," the progress knowledge is all but infinite as compared with that of e ages which preceded ours.

The believers in magic and miracles of a couple of nturies ago had all the strength of Mr. Mozley's present gic on their side. They had done for themselves what rejoices in having so effectually done for us—cleared e ground of the belief in the order of nature, and de-ared magic, miracles, and witchcraft to be matters for ordinary evidence" to decide. "The principle of mir-les" thus "befriended" had free scope, and we know e result. Lacking that rock-barrier of natural knowl-lge which we now possess, keen jurists and cultivated en were hurried on to deeds, the bare recital of which akes the blood run cold. Skilled in all the rules of hu-an evidence, and versed in all the arts of cross-examina-on, these men, nevertheless, went systematically astray, d committed the deadliest wrongs against humanity. nd why? Because they could not put Nature into the itness-box, and question her—of her voiceless "testi-ony" they knew nothing. In all cases between man and an, their judgment was to be relied on; but in all cases etween man and nature, they were blind leaders of the ind.[1]

[1] "In 1664 two women were hung in Suffolk, under a sentence of Sir atthew Hale, who took the opportunity of declaring that the reality of witch-aft was unquestionable; 'for first, the Scriptures had affirmed so much; and condly, the wisdom of all nations had provided laws against such persons, hich is an argument of their confidence of such a crime.' Sir Thomas Browne, o was a great physician as well as a great writer, was called as a witness, d swore 'that he was clearly of opinion that the persons were bewitched.'" Lecky's "History of Rationalism," vol. i. p. 120.

tious, "because it is easy to satisfy those who re-
quire." But he does consider it "a great result" that
ey have been accepted by the educated. In what sense
ucated? Like those statesmen, jurists and church dig-
taries whose education was unable to save them from
e frightful errors glanced at above? Not even in this
nse; for the great mass of Mr. Mozley's educated people
d no legal training, and must have been absolutely
nceless against delusions which could set even that train-
g at naught. Like nine-tenths of our clergy at the pre-
t day, they were versed in the literature of Greece,
ome and Judea; but as regards a knowledge of nature,
hich is here the one thing needful, they were "mere
vages," and nothing more. In the case of miracu-
en, it behooves us to understand the weight of the neg-
re, before we assign a value to the positive; to compre-
nd the depositions of nature, before we attempt to esti-
e, with them, the evidence of men. We have only
en our eyes to see what honest and even intellectual
en and women are capable of, as to judging evidence
this nineteenth century of the Christian era, and in lati-
de fifty-two degrees north. The experience thus gained
ght, I imagine, to influence our opinion regarding the
stimony of people inhabiting a sunnier clime, with a
cher imagination, and without a particle of that restraint
hich the discoveries of physical science have imposed
pon mankind.

his character. Though barely known to hi
his recent death affected me as that of a
regard to the style of his book, I heartily su
description with which the "Times" winds u
appreciative review. "It is marked throug
most serious and earnest conviction, but is
gle word from first to last of asperity or insin
opponents; and this not from any deficiency
to the importance of the issue, but from a
resolutely maintained self-control, and from a
ever-present sense of the duty, on themes li
more than judicial calmness."

[To the argument regarding the quantity
ulous, introduced at page 21, Mr. Mozley
the honor of publishing a Reply in the se
of the "Contemporary Review."—J. T.]

ADDITIONAL REMARKS ON MI

AMONG the scraps of manuscript, writte
when Mr. Mozley's work occupied my att
the following reflections:

With regard to the influence of modern
Mr. Mozley rates so low, one obvious effe
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and to increase proportionably the difficul
The ancients knew but little of the vastne

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compliance with his prayers, changes should occur in
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e popular belief in their orderly progression.

As a natural consequence the demand for evidence
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an illustration the miracle by which the victory
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whole day" upon Gibeon, and the moon in the vall
Ajalon. An Englishman of average education at
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uld have satisfied an Israelite in the age succeedi
at of Joshua. For, to the one, the miracle probably c
ted in the stoppage of a fiery ball less than a yard
ameter, while to the other it would be the stoppa
an orb fourteen hundred thousand times the earth

the "firmament of heaven"; and Sir George Airy refers to the case of a Greek philosopher who was persecuted for hazarding the assertion, then deemed monstrous, that the sun might be as large as the whole country of Greece. The concerns of a universe, regarded from this point of view, were much more commensurate with man and his concerns than those of the universe which science now reveals to us; and hence that to suit man's purposes, or that in compliance with his prayers, changes should occur in the order of the universe, was more easy of belief in the ancient world than it can be now. In the very magnitude which it assigns to natural phenomena, science has augmented the distance between them and man, and increased the popular belief in their orderly progression.

As a natural consequence the demand for evidence is more exacting than it used to be, whenever it is affirmed that the order of nature has been disturbed. Let us take as an illustration the miracle by which the victory of Joshua over the Amorites was rendered complete. In this case the sun is reported to have stood still for "about a whole day" upon Gibeon, and the moon in the valley of Ajalon. An Englishman of average education at the present day would naturally demand a greater amount of evidence to prove that this occurrence took place, than would have satisfied an Israelite in the age succeeding that of Joshua. For, to the one, the miracle probably consisted in the stoppage of a fiery ball less than a yard in diameter, while to the other it would be the stoppage of an orb fourteen hundred thousand times the earth in size. And even accepting the interpretation that Joshua dealt with what was apparent merely, but that what really occurred was the suspension of the earth's rotation, I

think the right to exercise a greater reserve in accepting the miracle, and to demand stronger evidence in support of it than that which would have satisfied an ancient Israelite, will still be conceded to a man of science.

There is a scientific as well as a historic imagination; and when, by the exercise of the former, the stoppage of the earth's rotation is clearly realized, the event assumes proportions so vast, in comparison with the result to be obtained by it, that belief reels under the reflection. The energy here involved is equal to that of six trillions of horses working for the whole of the time employed by Joshua in the destruction of his foes. The amount of power thus expended would be sufficient to supply every individual of an army a thousand times the strength of that of Joshua, with a thousand times the fighting power of each of Joshua's soldiers, not for the few hours necessary to the extinction of a handful of Amorites, but for millions of years. All this wonder is silently passed over by the sacred historian, manifestly because he knew nothing about it. Whether, therefore, we consider the miracle as purely evidential, or as a practical means of vengeance, the same lavish squandering of energy stares us in the face. If evidential, the energy was wasted, because the Israelites knew nothing of its amount; if simply destructive, then the ratio of the quantity lost to the quantity employed may be inferred from the foregoing figures.

To other miracles similar remarks apply. Transferring our thoughts from this little sand-grain of an earth to the immeasurable heavens, where countless worlds with freights of life probably revolve unseen, the very suns which warm them being barely visible across abysmal space; reflecting that beyond these sparks of solar fire, suns innumerable

may burn, whose light can never stir the optic nerve at all; and bringing these reflections face to face with the idea of the Builder and Sustainer of it all showing Himself in a burning bush, exhibiting His hinder parts, or behaving in other familiar ways ascribed to Him in the Jewish Scriptures, the incongruity must appear. Did the credulous prattle of the ancients about miracles stand alone; were it not associated with words of imperishable wisdom, and with examples of moral grandeur unmatched elsewhere in the history of the human race, both the miracles and their "evidences" would have long since ceased to be the transmitted inheritance of intelligent men. Influenced by the thoughts which this universe inspires, well may we exclaim in David's spirit, if not in David's words: "When I consider the heavens, the work of Thy fingers, the moon, and the stars, which Thou hast ordained, what is man that Thou shouldst be mindful of him, or the son of man that Thou shouldst so regard him?"

If you ask me who is to limit the outgoings of Almighty power, my answer is, Not I. If you should urge that if the Builder and Maker of this universe chose to stop the rotation of the earth, or to take the form of a burning bush, there is nothing to prevent Him from doing so, I am not prepared to contradict you. I neither agree with you nor differ from you, for it is a subject of which I know nothing. But I observe that in such questions regarding Almighty power, your inquiries relate, not to that power as it is actually displayed in the universe, but to the power of your own imagination. Your question is, not has the Omnipotent done so and so? or is it in the least degree likely that the Omnipotent should do so and so? but, is my imagination competent to picture a Being

Prayer as a means to effect a private end is theft and mendicancy.—EMERSON.

III

ON PRAYER AS A FORM OF PHYSICAL ENERGY

THE Editor of the "Contemporary Review" is liberal enough to grant me space for some remarks upon a subject which, though my relation to it was simply that of a vehicle of transmission, has brought down upon me a considerable amount of animadversion.

It may be interesting to some of my readers if I glance at a few cases illustrative of the history of the human mind, in relation to this and kindred questions. In the fourth century the belief in Antipodes was deemed unscriptural and heretical. The pious Lactantius was as angry with the people who held this notion as my censors are now with me, and quite as unsparing in his denunciations of their "Monstrosities." Lactantius was irritated because, in his mind, by education and habit, cosmogony and religion were indissolubly associated, and, therefore, simultaneously disturbed. In the early part of the seventeenth century the notion that the earth was fixed, and that the sun and stars revolved round it daily, was interwoven with religious feeling, the separation then attempted by Galileo rousing the animosity and kindling the persecution of the Church. Men still living can re-

mber the indignation excited by the first revelations geology regarding the age of the earth, the association ween chronology and religion being for the time in-soluble. In our day, however, the best-informed the-gians are prepared to admit that our views of the Uni-se and its Author are not impaired, but improved, by abandonment of the Mosaic account of the Creation. ok, finally, at the excitement caused by the publication the "Origin of Species"; and compare it with the calm endant on the appearance of the far more outspoken, l, from the old point of view, more impious, "Descent Man."

Thus religion survives after the removal of what had n long considered essential to it. In our day the tipodes are accepted; the fixity of the earth is given the period of Creation and the reputed age of the rld are alike dissipated; Evolution is looked upon hout terror; and other changes have occurred in the ne direction too numerous to be dwelt upon here. In t, from the earliest times to the present, religion has n undergoing a process of purification, freeing itself wly and painfully from the physical errors which the ive but uninformed intellect mingled with the aspira-ns of the soul. Some of us think that a final act of rification is needed, while others oppose this notion h the confidence and the warmth of ancient times. e bone of contention at present is *the physical value prayer.* It is not my wish to excite surprise, much to draw forth protest, by the employment of this rase. I would simply ask any intelligent person to k the problem honestly in the face, and then to say ether, in the estimation of the great body of those who

sincerely resort to it, prayer does not, at all events upon special occasions, invoke a Power which checks and augments the descent of rain, which changes the force and direction of winds, which affects the growth of corn and the health of men and cattle—a Power, in short, which, when appealed to under pressing circumstances, produces the precise effects caused by physical energy in the ordinary course of things. To any person who deals sincerely with the subject, and refuses to blur his moral vision by intellectual subtleties, this, I think, will appear a true statement of the case.

It is under this aspect alone that the scientific student, so far as I represent him, has any wish to meddle with prayer. Forced upon his attention as a form of physical energy, or as the equivalent of such energy, he claims the right of subjecting it to those methods of examination from which all our present knowledge of the physical universe is derived. And if his researches lead him to a conclusion adverse to its claims—if his inquiries rivet him still closer to the philosophy implied in the words, "He maketh His sun to shine on the evil and on the good, and sendeth rain upon the just and upon the unjust"—he contends only for the displacement of prayer, not for its extinction. He simply says, physical nature is not its legitimate domain.

This conclusion, moreover, must be based on pure physical evidence, and not on any inherent unreasonableness in the act of prayer. The theory that the system of nature is under the control of a Being who changes phenomena in compliance with the prayers of men is, in my opinion, a perfectly legitimate one. It may of course be rendered futile by being associated

with conceptions which contradict it; but such conceptions form no necessary part of the theory. It is a matter of experience that an earthly father, who is at the same time both wise and tender, listens to the requests of his children, and, if they do not ask amiss, takes pleasure in granting their requests. We know also that this compliance extends to the alteration, within certain limits, of the current of events on earth. With this suggestion offered by experience, it is no departure from scientific method to place behind natural phenomena a Universal Father, who, in answer to the prayers of His children, alters the currents of those phenomena. Thus far Theology and Science go hand in hand. The conception of an ether, for example, trembling with the waves of light, is suggested by the ordinary phenomena of wave-motion in water and in air; and in like manner the conception of personal volition in nature is suggested by the ordinary action of man upon earth. I therefore urge no *impossibilities*, though I am constantly charged with doing so. I do not even urge inconsistency, but, on the contrary, frankly admit that the theologian has as good a right to place his conception at the root of phenomena as I have to place mine.

But without *verification* a theoretic conception is a mere figment of the intellect, and I am sorry to find us parting company at this point. The region of theory, both in science and theology, lies behind the world of the senses, but the verification of theory occurs in the sensible world. To check the theory we have simply to compare the deductions from it with the facts of observation. If the deductions be in accordance with the facts, we accept the theory: if in opposition, the theory is given

up. A single experiment is frequently devised, by which the theory must stand or fall. Of this character was the determination of the velocity of light in liquids, as a crucial test of the Emission Theory. According to it, light travelled faster in water than in air; according to the Undulatory Theory, it travelled faster in air than in water. An experiment suggested by Arago, and executed by Fizeau and Foucault, was conclusive against Newton's theory.

But while science cheerfully submits to this ordeal, it seems impossible to devise a mode of verification of their theories which does not rouse resentment in theological minds. Is it that, while the pleasure of the scientific man culminates in the demonstrated harmony between theory and fact, the highest pleasure of the religious man has been already tasted in the very act of praying, prior to verification, any further effort in this direction being a mere disturbance of his peace? Or is it that we have before us a residue of that mysticism of the Middle Ages, so admirably described by Whewell: that "practice of referring things and events not to clear and distinct notions, not to general rules capable of direct verification, but to notions vague, distant, and vast, which we cannot bring into contact with facts; as when we connect natural events with moral and historic causes?" "Thus," he continues, "the character of mysticism is that it refers particulars, not to generalizations, homogeneous and immediate, but to such as are heterogeneous and remote; to which we must add that the process of this reference is not a calm act of the intellect, but is accompanied with a glow of enthusiastic feeling."

Every feature here depicted, and some more ques-
ionable ones, have shown themselves of late; most con-
picuously, I regret to say, in the "leaders" of a weekly
ournal of considerable influence, and one, on many
rounds, entitled to the respect of thoughtful men. In
he correspondence, however, published by the same jour-
ial, are to be found two or three letters well calculated
o correct the temporary flightiness of the journal itself.

It is not my habit of mind to think otherwise than
olemnly of the feeling which prompts prayer. It is a
ower which I should like to see guided, not extin-
uished—devoted to practicable objects instead of wasted
pon air. In some form or other, not yet evident, it
nay, as alleged, be necessary to man's highest culture.
'ertain it is that, while I rank many persons who resort
o prayer low in the scale of being—natural foolishness,
igotry, and intolerance being in their case intensified by
he notion that they have access to the ear of God—I
egard others who employ it as forming part of the very
ream of the earth. The faith that adds to the folly and
erocity of the one is turned to enduring sweetness, holi-
iess, abounding charity, and self-sacrifice by the other.
Religion, in fact, varies with the nature upon which it
alls. Often unreasonable, if not contemptible, prayer,
n its purer forms, hints at disciplines which few of us
an neglect without moral loss. But no good can come
of giving it a delusive value, by claiming for it a power
n physical nature. It may strengthen the heart to meet
ife's losses, and thus indirectly promote physical well-
being, as the digging of Æsop's orchard brought a treas-
ure of fertility greater than the golden treasure sought.
Such indirect issues we all admit; but it would be sim-

ply dishonest to affirm that it is such issues that are always in view. Here, for the present, I must end. I ask no space to reply to those railers who make such free use of the terms insolence, outrage, profanity, and blasphemy. They obviously lack the sobriety of mind necessary to give accuracy to their statements, or to render their charges worthy of serious refutation.

IV

VITALITY

THE origin, growth, and energies of living things are subjects which have always engaged the attention of thinking men. To account for them it was usual to assume a special agent, free to a great extent from the limitations observed among the powers of inorganic nature. This agent was called *vital force;* and, under its influence, plants and animals were supposed to collect their materials and to assume determinate forms. Within the last few years, however, our ideas of vital processes have undergone profound modifications; and the interest, and even disquietude, which the change has excited are amply evidenced by the discussions and protests which are now common regarding the phenomena of vitality. In tracing these phenomena through all their modifications, the most advanced philosophers of the present day declare that they ultimately arrive at a single source of power, from which all vital energy is derived; and the disquieting circumstance is that this source is not the direct fiat of a supernatural agent, but a reservoir of what, if we do not accept the creed of Zoroaster, must be regarded as *inorganic* force. In short, it is considered as proved that all the energy which we derive from plants and animals is drawn from the sun.

A few years ago, when the sun was affirmed to be the

source of life, nine out of ten of those who are alarmed by the form which this assertion has latterly assumed would have assented, in a general way, to its correctness. Their assent, however, was more poetic than scientific, and they were by no means prepared to see a rigid mechanical signification attached to their words. This, however, is the peculiarity of modern conclusions: that there is no creative energy whatever in the vegetable or animal organism, but that all the power which we obtain from the muscles of man and animals, as much as that which we develop by the combustion of wood or coal, has been produced at the sun's expense. The sun is so much the colder that we may have our fires; he is also so much the colder that we may have our horse-racing and Alpine climbing. It is, for example, certain that the sun has been chilled to an extent capable of being accurately expressed in numbers, in order to furnish the power which lifted this year a certain number of tourists from the vale of Chamouni to the summit of Mont Blanc.

To most minds, however, the energy of light and heat presents itself as a thing totally distinct from ordinary mechanical energy. Either of them can nevertheless be derived from the other. Wood can be raised by friction to the temperature of ignition; while by properly striking a piece of iron a skilful blacksmith can cause it to glow. Thus, by the rude agency of his hammer, he generates light and heat. This action, if carried far enough, would produce the light and heat of the sun. In fact, the sun's light and heat have actually been referred to the fall of meteoric matter upon his surface; and whether the sun is thus supported or not, it is perfectly certain that he *might be* thus supported. Whether, moreover, the

whilom molten condition of our planet was, as supposed by eminent men, due to the collision of cosmic masses or not, it is perfectly certain that the molten condition *might be* thus brought about. If, then, solar light and heat can be produced by the impact of dead matter, and if from the light and heat thus produced we can derive the energies which we have been accustomed to call *vital*, it indubitably follows that vital energy may have a proximately mechanical origin.

In what sense, then, is the sun to be regarded as the origin of the energy derivable from plants and animals? Let us try to give an intelligible answer to this question. Water may be raised from the sea-level to a high elevation, and then permitted to descend. In descending it may be made to assume various forms—to fall in cascades, to spurt in fountains, to boil in eddies, or to flow tranquilly along a uniform bed. It may, moreover, be caused to set complex machinery in motion, to turn millstones, throw shuttles, work saws and hammers, and drive piles. But every form of power here indicated would be derived from the original power expended in raising the water to the height from which it fell. There is no energy *generated* by the machinery: the work performed by the water in descending is merely the parcelling out and distribution of the work expended in raising it. In precisely this sense is all the energy of plants and animals the parcelling out and distribution of a power originally exerted by the sun. In the case of the water, the source of the power consists in the forcible separation of a quantity of the liquid from a low level of the earth's surface, and its elevation to a higher position, the power thus expended being returned by the water in its descent.

In the case of vital phenomena, the source of power consists in the forcible separation of the atoms of compound substances by the sun. We name the force which draws the water earthward "gravity," and that which draws atoms together "chemical affinity"; but these different names must not mislead us regarding the qualitative identity of the two forces. They are both *attractions*; and, to the intellect, the falling of carbon atoms against oxygen atoms is not more difficult of conception than the falling of water to the earth.

The building up of the vegetable, then, is effected by the sun, through the reduction of chemical compounds. The phenomena of animal life are more or less complicated reversals of these processes of reduction. We eat the vegetable, and we breathe the oxygen of the air; and in our bodies the oxygen, which had been lifted from the carbon and hydrogen by the action of the sun, again falls toward them, producing animal heat and developing animal forms. Through the most complicated phenomena of vitality this law runs the vegetable is produced while a weight rises, the animal is produced while a weight falls. But the question is not exhausted here. The water employed in our first illustration generates all the motion displayed in its descent, but the *form* of the motion depends on the character of the machinery interposed in the path of the water. In a similar way, the primary action of the sun's rays is qualified by the atoms and molecules among which their energy is distributed. Molecular forces determine the form which the solar energy will assume. In the separation of the carbon and oxygen this energy may be so conditioned as to result in one case in the formation of a cabbage,

and in another case in the formation of an oak. So also, as regards the reunion of the carbon and the oxygen, the molecular machinery through which the combining energy acts may, in one case, weave the texture of a frog, while in another it may weave the texture of a man.

The matter of the animal body is that of inorganic nature. There is no substance in the animal tissues which is not primarily derived from the rocks, the water, and the air. Are the forces of organic matter, then, different in kind from those of inorganic matter? The philosophy of the present day negatives the question. It is the compounding, in the organic world, of forces belonging equally to the inorganic, that constitutes the mystery and the miracle of vitality. Every portion of every animal body may be reduced to purely inorganic matter. A perfect reversal of this process of reduction would carry us from the inorganic to the organic; and such a reversal is at least conceivable. The tendency, indeed, of modern science is to break down the wall of partition between organic and inorganic, and to reduce both to the operation of forces which are the same in kind, but which are differently compounded.

Consider the question of personal identity, in relation to that of molecular form. Thirty-four years ago, Mayer of Heilbronn, with that power of genius which breathes large meanings into scanty facts, pointed out that the blood was "the oil of the lamp of life," the combustion of which sustains muscular action. The muscles are the machinery by which the dynamic power of the blood is brought into play. Thus the blood is consumed. But the whole body, though more slowly than the blood, wastes also, so that after a certain number of years it

is entirely renewed. How is the sense o
tity maintained across this flight of mole
as we know him, matter is necessary t
but the matter of any period may be all
consciousness exhibits no solution of c
changing sentinels, the oxygen, hydrog
that depart, seem to whisper their secr
rades that arrive, and thus, while the
the Ego remains the same. Constancy
grouping of the molecules, and not c
molecules themselves, is the correlative o
of perception. Life is a *wave* which in
tive moments of its existence is compo
particles.

Supposing, then, the molecules of th
instead of replacing others, and thus
existing form, to be gathered first hand
put together in the same relative position
they occupy in the body. Supposing th
self-same forces and distribution of force
motions and distribution of motions—wo
ized concourse of molecules stand before
thinking being? There seems no valid r
that it would not. Or, supposing a pla

and who will set limits to the possible p
cules in a cooling planet? If these state
it is because matter has been defined a
by philosophers and theologians, who were
aware that it is, at bottom, essentially
transcendental.

Questions such as these derive their p
in great part from their audacity, which is
time, to disappear. And the sooner the p
abolished with reference to such questions the
cause of truth. As regards knowledge, ph
is polar. In one sense it knows, or is dest
everything. In another sense it knows not
understands much of this intermediate ph
that we call nature, of which it is the
science knows nothing of the origin or dest
Who or what made the sun, and gave his
leged power? Who or what made and b
the ultimate particles of matter their wond
varied interaction? Science does not know
though pushed back, remains unaltered. T
who feel that there are more things in hea
than are dreamed of in the present philosop
but who have been also taught, by baffle
vain is the attempt to grapple with the I
ultimate frame of mind is that of Goethe:

As I rode through the Schwarzwald, I said to myse
glows star-like across the dark-growing moor, where th
his anvil, and thou hopest to replace thy lost horseshoe
rated speck, cut off from the whole Universe; or indissol
Thou fool, that smithy-fire was primarily kindled at the
circulates from before Noah's Deluge, from beyond th
Iron Force, and Coal Force, and the far stranger For
affinities and battles and victories of Force brought alo
or nervous centre, in the great vital system of Immensi
an unconscious Altar, kindled on the bosom of the Al
rated! I say there is no such separation: nothing hit
cast aside; but all, were it only a withered leaf, wor
borne forward on the bottomless, shoreless flood of a
perpetual metamorphoses.—CARLYLE

V

MATTER AND FORCE [1]

IT is the custom of the Professors in
of Mines in London to give course
ures every year to working men.
holds 600 people; and tickets to this
posed of as quickly as they can be han
apply for them. So desirous are the

hardly ever of a nature which admits of
into money. It is, therefore, a pure desi
edge, as a thing good in itself, and without
practical application, which animates the he
lectures.

It is also my privilege to lecture to anc
in London, composed in part of the aristoc
while the audience just referred to is compo
the aristocracy of labor. As regards attenti
esy to the lecturer, neither of these audie
thing to learn of the other; neither can cla
over the other. It would not, perhaps, be
to take those persons who flock to the Sc
as average samples of their class; they
picked men—the aristocracy of labor, as
called them. At all events, their conduct
that the essential qualities of what we in E
stand by a gentleman are confined to no cl
have often raised in my mind the wish th
men of all classes, artisans as well as lor
some process of selection, be sifted from the
of the community, and caused to know each

When pressed some months ago by the
British Association to give an evening
working men of Dundee, my experience of
men of London naturally rose to my mind
heavily weighted with other duties, I cou
myself to decline the request of the Counc

livered before its members and asso
after the meeting at Nottingham, las
working men, at their own request,
our late President, Mr. Grove, and
friend, Professor Huxley, the idea ar
ing with all subsequent meetings of t
address to the working men of the t
meeting is held. A resolution to that
the Committee of Recommendations; t
ported the resolution; the Council of th
fied the decision of the Committee;
carry out to the best of my ability the

Whether it be a consequence of
velopment, or an endowment conferre
man at his creation, we find him h
mind curious to know the causes of
rounded by objects which excite its
raise the desire for an explanation.
young Prince of one of the Pacific is
first saw himself in a looking-glass he
to see who was standing at the back
with the general human intellect, as r
ena of the external world. It wishes

e, so to speak, the complement of nature's facts, within certain limits, the secret of the universe to the human understanding. It was found that l of man had the power of penetrating far be boundaries of his five senses; that the things w seen in the material world depend for their a things unseen; in short, that besides the phe which address the senses, there are laws and s and processes which do not address the sens but which must be, and can be, spiritually disce To the subjects which require this discernment be phenomena of molecular force. But to trace sis of the notions now entertained upon this we have to go a long way back. In the dra a bow, the darting of a javelin, the throwing e—in the lifting of burdens, and in personal —even savage man became acquainted with ration of *force*. Ages of discipline, moreover, ta foresight. He laid by at the proper season s food, thus obtaining time to look about him, an ome an observer and inquirer. Two things whic eed must have profoundly stirred his curiosity. d that a kind of resin dropped from a certain

the magnet and the amber, pulls and
and repulsions—were also exerted; a
poetic transfer, he applied to things
conceptions derived from himself. Th
rubbed amber were credited with pus
or, in other words, with exerting forc

In the time of the great Lord Ba
these pushes and pulls was vastly ext
bert, a man probably of firmer scientific
insight, than Bacon himself. Gilbert
titude of other bodies, when rubbed,
which, thousands of years previously,
in amber. In this way the notion of
pulsion in external nature was rendere
a matter of experience that bodies,
visible link or connection existed, po
of acting upon each other; and the
technically called "action at a distanc

But out of experience in science
thing finer than mere experience. E
the soil for plants of higher growth;
tion of action at a distance provided
lation upon the largest of problems.
served to fall to the earth. Why sh

as a boy twirls round his head a bullet at
string. But why should the chain be ne
a fact of experience that bodies can attra
at a distance, without the intervention o
Why should not the sun and earth so
other? and why should not the fall of b
height be the result of their attraction b
Here then we reach one of those higher
which grow out of the fruitful soil of
Having started with the savage, and his
muscular force, we pass on to the observa
exerted between a magnet and rubbed an
bodies which they attract, rising, by an unb
of ideas, to a conception of the force by w
planets are held together.

This idea of attraction between sun and
become familiar in the time of Newton. E
to examine the attraction; and here, as
find the speculative mind falling back for
upon experience. It had been observed, i
magnetic and electric bodies, that the near
brought together the stronger was the forc
tween them; while, by increasing the dista

of variation with the distance. But
result Newton found room for other
of which, indeed, constituted the
stones to his result. The one which
is, that not only does the sun attract
earth attract the sun, *as wholes*, bu
the sun attracts every particle of the
verse. His conclusion was that the
masses was simply the sum of the
constituent particles.

This result seems so obvious tha
wonder at my dwelling upon it; but
turning point in our notions of forc
ably heard of certain philosophers of
named Democritus, Epicurus, and Lu
adopted, developed, and diffused the
and molecules, which found its co
hands of the illustrious John Dalto
and Roman philosophers I have nar
lowers, up to the time of Newton, p
as falling and flying through space,
and clinging together by imaginary
They missed the central idea that a
could come together, not by being f

repels, the north pole of the needle
be as perfect a magnet as the wh
this half and go on till further bre
sible through the very smallness o
smallest fragment is found endowed
is, therefore, a perfect magnet. I
here: you *imagine* where you ca
reach the conclusion entertained b
that the magnet which you see a
blage of molecular magnets which
feel, but which, as before stated,
discerned.

Magnetism then is a polar force;
that a force of this kind may exer
power. It is known, for examp
strewn round a magnet arrange t
lines, called, by some, "magnetic c
ers, "lines of magnetic force." O
before me is spread a sheet of pa
filings over the paper, polar force
every particle of the iron respond
have a kind of architectural effor
term—exerted on the part of the
then is a fact of experience wh
immediately furnishes further mat

processes of chemistry are examples of these. I
king and experimenting has led philosophers to
le that matter is composed of atoms from wh
ther separate or in combination, the whole mat
ld is built up. The air we breathe, for exampl
nly a mechanical mixture of the atoms of oxygen
ogen. The water we drink is also composed of
and hydrogen. But it differs from the air in
icular, that in water the oxygen and hydrogen
mechanically mixed, but chemically combined.
ns of oxygen and those of hydrogen exert enorm
actions on each other, so that when brought
cient proximity they rush together with an al
edible force to form a chemical compound.
erful as is the force with which these atoms
nselves together, we have the means of tearing
nder, and the agent by which we accomplish this
receive a few moments' attention.

Into a vessel containing acidulated water I dip
s of metal, the one being zinc and the other p
, not permitting them to touch each other in
id. I connect the two upper ends of the strips
ece of copper wire. The wire is now the chann
t, for want of a better name, we call an "electric

employ the self-same wire to connec
the battery, and subject it to the sa
filings now crowd round the wire
interrupt the current, and the filings
the power of attraction continues o
wire connects the two ends of the bat

Here is a piece of similar wire, ov
to prevent the contact of its various
into a coil. I make the coil part of
necta the two ends of the voltaic bat
tive force with which it has become
it now empties this tool-box of its i
covered copper wire round this comm
ing the wire with the two ends of th
poker is instantly transformed into a s
flat spirals are here suspended facin
six inches apart. Sending a current
rals, they clash suddenly together;
called the direction of the current in
they fly asunder. All these effects ar
which we name an electric current, a
as flowing through the wire when t
complete.

By the same agent we tear asunde

vaporous condition, the play of this force is a
ner masked and hidden. But as the heat is gradu
ndrawn, the molecules prepare for new arrangem
combinations. Solid crystals of water are at len
ned, to which we give the familiar name of
king at these beautiful edifices and their inte
cture, the pondering mind has forced upon it
stion, How are they built up? We have obtai
r conceptions of polar force; and we infer from
ken magnet that polar force may be resident in
lecules or smallest particles of matter, and that
play of this force structural arrangement is possi
hat, in relation to our present question, is the nat
ion of a mind furnished with this knowledge? I
npelled to transcend experience, and endow the at
d molecules of which crystals are built with defi
les whence issue attractions and repulsions. In vi
these forces some poles are drawn together, w
me retreat from each other; atom is added to at
d molecule to molecule, not boisterously or for
usly, but silently and symmetrically, and in acc
ce with laws more rigid than those which guid
man builder when he places his materials toget
agine the bricks and stones of this town of Dun
dowed with structural power. Imagine them attract
d repelling, and arranging themselves into streets
uses and Kinnaird Halls—would not that be wonderf
ardly less wonderful is the play of force by which

d. A reversal of the process of crystallization may
ually shown. The molecules of a piece of ice
taken asunder before your eyes; and from the m
in which they separate, you may to some ex
er the manner in which they go together. Whe
m is sent from our electric lamp through a plate
ss, a portion of the beam is intercepted, and the g
warmed by the portion thus retained within it. W
beam is sent through a plate of ice, a portion of
m is also absorbed; but instead of warming the
intercepted heat melts it internally. It is to
icate silent action of this beam within the ice th
w wish to direct your attention. Upon the screen
own a magnified image of the slab of ice: the l
the beam passes freely through the ice without m
it, and enables us to form the image; but the
in great part intercepted, and that heat now app
elf to the work of internal liquefaction. Selecting
n points for attack, round about those points the b
rks silently, undoing the crystalline architecture,
lucing to the freedom of liquidity molecules which
en previously locked in a solid embrace. The lique
ces are rendered visible by strong illumination.
ve those six-petalled flowers breaking out over the w
rface, and expanding in size as the action of the b
ntinues. These flowers are liquefied ice. Under
ion of the heat the molecules of the crystals fall as
r, so as to leave behind them these exquisite for

nerican poet, "the atoms march in tune," movin
e music of law, which thus renders the commo
ostance in nature a miracle of beauty.

It is the function of science, not, as some think
rest this universe of its wonder and mystery, but
the case before us, to point out the wonder and
stery of common things. Those fern-like forms, wl
a frosty morning overspread your window panes, il
te the action of the same force. Breathe upon suc
ne before the fires are lighted, and reduce the s
stalline film to the liquid condition; then watch
osequent resolidification. You will see it all the be
you look at it through a common magnifying gla
ter you have ceased breathing, the film, abando
the action of its own forces, appears for a mom
be alive. Lines of motion run through it; molec
ses with molecule, until finally the whole film pa
m the state of liquidity, through this state of moti
its final crystalline repose.

I can show you something similar. Over a piece
fectly clean glass I pour a little water in which
n crystals have been dissolved. A film of the s
n clings to the glass. By means of a microscope an
np, an image of the plate of glass is thrown upon
een. The beam of the lamp, besides illuminating
ss, also heats it; evaporation sets in, and at a cert
ment, when the solution has become

m distant nuclei in the middle of the field of
spears shoot with magical rapidity in all direct
film of water on a window-pane on a frosty mo
ibits effects quite as wonderful as these. Later
se formless solutions, latent in every drop of w
this marvellous structural power, which only req
withdrawal of opposing forces to bring it into actio
The clear liquid now held up before you is a sol
nitrate of silver—a compound of silver and nitric
en an electric current is sent through this liqui
er is severed from the acid, as the hydrogen was
ed from the oxygen in a former experiment; a
ld ask you to observe how the metal behaves
molecules are thus successively set free. The i
the cell, and of the two wires which dip into
id of the cell, are now clearly shown upon
en. Let us close the circuit, and send the cu
ough the liquid. From one of the wires a beau
er tree commences immediately to sprout. Bran
the metal are thrown out, and umbrageous fo
ls the branches. You have here a growth, a
y as wonderful as that of any vegetable, perf
a minute before your eyes. Substituting for th
e of silver acetate of lead, which is a compoun
l and acetic acid, the electric current severs the
n the acid, and you see the metal slowly branc
exquisite metallic ferns, the fronds of which, as

y, arranges itself, under the operation of these for
o forms which rival in beauty those of the veget
rld. And what is the vegetable world itself but
ult of the complex play of these molecular for
re, as elsewhere throughout nature, if matter m
s force that moves it, and if a certain structure, v
le or mineral, is produced, it is through the opera
the forces exerted between the atoms and molec
The solid matter of which our lead and silver t
re formed was, in the first instance, disguised i
nsparent liquid; the solid matter of which our w
l forests are composed is also, for the most part,
sed in a transparent gas, which is mixed in s
antities with the air of our atmosphere. This ga
med by the union of carbon and oxygen, and
ed carbonic acid gas. The carbonic acid of the
ng subjected to an action somewhat analogous to
the electric current in the case of our lead and si
utions, has its carbon liberated and deposited as wo
re. The watery vapor of the air is subjected to s
action; its hydrogen is liberated from its oxygen,
down side by side with the carbon in the tissue
tree. The oxygen in both cases is permitted to w
away into the atmosphere. But what is it in na
t plays the part of the electric current in our exp
nts, tearing asunder the locked atoms of carbon, o

those beautiful branching forms seen in our e
nts, so do the molecular attractions of the lib
rbon and hydrogen find expression in the archit
grasses, plants, and trees.

In the fall of a cataract and the rush of the wi
ve examples of mechanical power. In the com
ns of chemistry and in the formation of crystal
getables we have examples of molecular power.
ve learned how the atoms of oxygen and hyd
sh together to form water. I have not thought i
ary to dwell upon the mighty mechanical ener
eir act of combination; but it may be said, in pa
at the clashing together of 1 lb. of hydrogen and
oxygen to form 9 lbs. of aqueous vapor is
an the shock of a weight of 1,000 tons falling f
ight of 20 feet against the earth. Now, in orde
e atoms of oxygen and hydrogen should rise by
utual attractions to the velocity corresponding t
ormous mechanical effect, a certain distance must
tween the particles. It is in rushing over this th
locity is attained.

This idea of distance between the attracting ato
the highest importance in our conception of th
n of the world. For the matter of the world m
assified under two distinct heads: atoms and mol
ich have already combined and thus satisfied

cause sufficient distance intervenes between the attr
g atoms, and it is this atomic motion that we utiliz
r machines. Thus we can get power out of oxy
d hydrogen by the act of their union; but once t
e combined, and once the vibratory motion consequ
their combination has been expended, no furt
wer can be got out of their mutual attraction.
namic agents they are dead. The materials of
th's crust consist for the most part of substan
ose atoms have already closed in chemical unio
ose mutual attractions are satisfied. Granite, for
nce, is a widely diffused substance; but granite c
ts, in great part, of silicon, oxygen, potassium,
m, and aluminium, whose atoms united long a
d are therefore dead. Limestone is composed of c
n, oxygen, and a metal called calcium, the atoms
ich have already closed in chemical union, and
refore finally at rest. In this way we might go o
rly the whole of the materials of the earth's cr
d satisfy ourselves that though they were sources
wer in ages past, and long before any creature
red on the earth capable of turning their power
ount, they are sources of power no longer. And h
might halt for a moment to remark on that tenden
prevalent in the world, to regard everything as m
human use. Those who entertain this notion, h
think, an overweening opinion of their own imp

inheritance, and as brave ones not to whimper
ould prove less than we had supposed. The h
itude of mind with reference to this subject is
the poet, who, when asked whence came the rh
fully acknowledged his brotherhood with the flo

> Why thou wert there, O rival of the rose!
> I never thought to ask, I never knew,
> But in my simple ignorance supposed
> The self-same power that brought me there
> brought you.[1]

A few exceptions to the general state of union
lecules of the earth's crust—vast in relation to u
vial in comparison to the total store of which th
residue—still remain. They constitute our
urces of motive power. By far the most imp
these are our beds of coal. Distance still inter
ween the atoms of carbon and those of atmos
ygen, across which the atoms may be urged by
tual attractions; and we can utilize the motion
duced. Once the carbon and the oxygen have r
gether, so as to form carbonic acid, their mutual
ns are satisfied; and, while they continue in thi
ion, as dynamic agents they are dead. Our wood
ests are also sources of mechanical energy, becaus
ve the power of uniting with the atmospheric ox
ssing from plants to animals, we find that the

le this vital gas, and bring it into sufficiently c
oximity with the carbon and the hydrogen of the bo
ese unite in obedience to their mutual attractions;
ir motion toward each other, properly turned to
int by the wonderful mechanism of the body, becor
scular motion.

One fundamental thought pervades all these sta
nts: there is one tap-root from which they all spri
is is the ancient maxim that out of nothing noth
nes; that neither in the organic world nor in the
anic is power produced without the expenditure
ver; that neither in the plant nor in the animal
re a creation of force or motion. Trees grow, a
do men and horses; and here we have new pov
essantly introduced upon the earth. But its sour
I have already stated, is the sun. It is the sun t
arates the carbon from the oxygen of the carbo
l, and thus enables them to recombine. Wheth
y recombine in the furnace of the steam-engine
the animal body, the origin of the power they p
e is the same. In this sense we are all "souls of f
children of the sun." But, as remarked by Hel
tz, we must be content to share our celestial pedig
h the meanest of living things.

Some estimable persons, here present, very possib
nk from accepting these statements; they may
htened by their apparent tendency

own and avowed that the physical philosopher
h, must be a pure materialist. His inquiries
h matter and force, and with them alone.
atever be the forms which matter and force assu
ether in the organic world or the inorganic, whe
the coal-beds and forests of the earth, or in the br
muscles of men, the physical philosopher will n
d his right to investigate them. It is perfectly
attempt to stop inquiry in this direction. Dep
on it, if a chemist, by bringing the proper mate
ether in a retort or crucible, could make a baby
uld do it. There is no law, moral or physical, for
g him to do it. At the present moment there
doubt, persons experimenting on the possibility
ducing what we call life out of inorganic mater
them pursue their studies in peace; it is only
n trials that they will learn the limits of their
vers and the operation of the laws of matter
e.

But while thus making the largest demand for
n of investigation—while I consider science to be a
verful as an instrument of intellectual culture and
istrant to the material wants of men; if you ask
ether it has solved, or is likely in our day to so
problem of this universe, I must shake my hea
ht. You remember the first Napoleon's quest

ion of the problem. It entirely transcends us. The
nd of man may be compared to a musical instrum
th a certain range of notes, beyond which in both
tions we have an infinitude of silence. The phen
 of matter and force lie within our intellectual ran
d as far as they reach we will at all hazards push
quiries. But behind, and above, and around all,
l mystery of this universe lies unsolved, and, as far
 are concerned, is incapable of solution. Fashion t
stery as you will, with that I have nothing to
t let your conception of it not be an unworthy
vest that conception with your highest and hol
ught, but be careful of pretending to know m
out it than is given to man to know. Be care
ove all things, of professing to see in the phenom
the material world the evidences of Divine pleasure
pleasure. Doubt those who would deduce from
 of the tower of Siloam the anger of the Lord agai
se who were crushed. Doubt equally those who p
d to see in cholera, cattle-plague, and bad harve
dences of Divine anger. Doubt those spiritual gui
o in Scotland have lately propounded the monstr
ory that the depreciation of railway scrip is a con
ence of railway travelling on Sundays. Let them
 far as you are concerned, libel the system of nat
h their ignorant hypotheses. Looking from the s
les of thought into this highest of questions, and

in these islands his debtor—well, I say, might
ble old Carlyle scornfully retort on such interpret
ways of God to men:

> The Builder of this universe was wise,
>   He formed all souls, all systems, planets, particles;
> The plan he formed his worlds and Æons by,
>   Was—Heavens!—was thy small nine-and-thirty articles!

While sympathizing with each of its departments, and supplementing his culture by knowledge drawn from all of them, each student among us selects one subject for the exercise of his own original faculty—one line, along which he may carry the light of his private intelligence a little way into the darkness by which all knowledge is surrounded. Thus, the geologist deals with the rocks; the biologist with the conditions and phenomena of life; the astronomer with stellar masses and motions; the mathematician with the relations of space and number; the chemist pursues his atoms; while the physical investigator has his own large field in optical, thermal, electrical, acoustical, and other phenomena. The British Association then, as a whole, faces physical nature on all sides, and pushes knowledge centrifugally outward, the sum of its labors constituting what Fichte might call the *sphere* of natural knowledge. In the meetings of the Association it is found necessary to resolve this sphere into its component parts, which take concrete form under the respective letters of our Sections.

Mathematics and Physics have been long accustomed to coalesce, and here they form a single section. No matter how subtle a natural phenomenon may be, whether we observe it in the region of sense, or follow it into that of imagination, it is in the long run reducible to mechanical laws. But the mechanical data once guessed or given, mathematics are all-powerful as an instrument of deduction. The command of Geometry over the relations of space, and the far-reaching power which Analysis confers, are potent both as means of physical discovery, and of reaping the entire fruits of discovery. Indeed, without mathematics, expressed or implied, our

knowledge of physical science would be both friable and incomplete.

Side by side with the mathematical method we have the method of experiment. Here from a starting point furnished by his own researches or those of others, the investigator proceeds by combining intuition and verification. He ponders the knowledge he possesses, and tries to push it further; he guesses, and checks his guess; he conjectures, and confirms or explodes his conjecture. These guesses and conjectures are by no means leaps in the dark; for knowledge once gained casts a faint light beyond its own immediate boundaries. There is no discovery so limited as not to illuminate something beyond itself. The force of intellectual penetration into this penumbral region which surrounds actual knowledge is not, as some seem to think, dependent upon method, but upon the genius of the investigator. There is, however, no genius so gifted as not to need control and verification. The profoundest minds know best that Nature's ways are not at all times their ways, and that the brightest flashes in the world of thought are incomplete until they have been proved to have their counterparts in the world of fact. Thus the vocation of the true experimentalist may be defined as the continued exercise of spiritual insight, and its incessant correction and realisation. His experiments constitute a body, of which his purified intuitions are, as it were, the soul.

Partly through mathematical and partly through experimental research, physical science has, of late years, assumed a momentous position in the world. Both in a material and in an intellectual point of view it has produced, and it is destined to produce, immense changes—

ast social ameliorations, and vast alterations in the pop-
lar conception of the origin, rule, and governance of
atural things. By science, in the physical world, mir-
cles are wrought, while philosophy is forsaking its an-
ient metaphysical channels, and pursuing others which
ave been opened, or indicated, by scientific research.
This must become more and more the case as philosoph-
al writers become more deeply imbued with the meth-
ds of science, better acquainted with the facts which
cientific men have established, and with the great the-
ries which they have elaborated.

If you look at the face of a watch, you see the hour
nd minute hands, and possibly also a second hand, moving
ver the graduated dial. Why do these hands move?
nd why are their relative motions such as they are ob-
erved to be? These questions cannot be answered with-
ut opening the watch, mastering its various parts, and
scertaining their relationship to each other. When this
s done, we find that the observed motion of the hands
ollows of necessity from the inner mechanism of the watch
vhen acted upon by the force invested in the spring.
The motion of the hands may be called a phenomenon
f art, but the case is similar with the phenomena of
ature. These also have their inner mechanism and
heir store of force to set that mechanism going. The
ltimate problem of physical science is to reveal this
nechanism, to discern this store, and to show that, from
he combined action of both, the phenomena of which
hey constitute the basis, must, of necessity, flow.

I thought an attempt to give you even a brief and
ketchy illustration of the manner in which scientific
hinkers regard this problem would not be uninteresting.

you on the present occasion; more especially as it will ve me occasion to say a word or two on the tendencies ıd limits of modern science; to point out the region hich men of science claim as their own, and where it futile to oppose their advance; and also to define, if ossible, the bourne between this and that other region, which the questionings and yearnings of the scientific tellect are directed in vain.

But here your tolerance will be needed. It was the merican Emerson, I think, who said that it is hardly ssible to state any truth strongly, without apparent in- stice to some other truth. Truth is often of a dual aracter, taking the form of a magnet with two poles; d many of the differences which agitate the thinking rt of mankind are to be traced to the exclusiveness th which partisan reasoners dwell upon one half of the ality in forgetfulness of the other. The proper course pears to be to state both halves strongly, and allow ch its fair share in the formation of the resultant con- ction. But this waiting for the statement of the two des of a question implies patience. It implies a resolu- on to suppress indignation, if the statement of the one lf should clash with our convictions; and to repress ually undue elation, if the half-statement should hap- n to chime in with our views. It implies a determina- on to wait calmly for the statement of the whole, before e pronounce judgment in the form of either acquiescence dissent.

This premised, and I trust accepted, let us enter upon task. There have been writers who affirmed that the yramids of Egypt were natural productions; and in his rly youth Alexander von Humboldt wrote a learned

essay with the express object of refuting this notion
We now regard the Pyramids as the work of men'
hands, aided probably by machinery of which no recor
remains. We picture to ourselves the swarming worker
toiling at those vast erections, lifting the inert stones
and, guided by the volition, the skill, and possibly a
times by the whip of the architect, placing them in thei
proper positions. The blocks, in this case, were move
and posited by a power external to themselves, and th
final form of the pyramid expressed the thought of it
human builder.

Let us pass from this illustration of constructiv
power to another of a different kind. When a solutio
of common salt is slowly evaporated, the water whic
holds the salt in solution disappears, but the salt itse
remains behind. At a certain stage of concentration th
salt can no longer retain the liquid form; its particle
or molecules, as they are called, begin to deposit them
selves as minute solids—so minute, indeed, as to defy a
microscopic power. As evaporation continues, solidific
tion goes on, and we finally obtain, through the cluste
ing together of innumerable molecules, a finite crystallin
mass of a definite form. What is this form? It some
times seems a mimicry of the architecture of Egypt. W
have little pyramids built by the salt, terrace above te
race from base to apex, forming a series of steps resem
bling those up which the traveller in Egypt is dragge
by his guides. The human mind is as little disposed t
look without questioning at these pyramidal salt-crystal
as to look at the Pyramids of Egypt, without inquirin
whence they came. How, then, are those salt-pyramid
built up?

Guided by analogy, you may, if you like, suppose
t, swarming among the constituent molecules of the
, there is an invisible population, controlled and co-
ed by some invisible master, placing the atomic blocks
their positions. This, however, is not the scientific
a, nor do I think your good sense will accept it as
ikely one. The scientific idea is that the molecules
upon each other without the intervention of slave
or; that they attract each other, and repel each other,
certain definite points, or poles, and in certain definite
ections; and that the pyramidal form is the result of
play of attraction and repulsion. While, then, the
cks of Egypt were laid down by a power external to
mselves, these molecular blocks of salt are self-posited,
ng fixed in their places by the inherent forces with
ch they act upon each other.

I take common salt as an illustration, because it is so
iliar to us all; but any other crystalline substance
ld answer my purpose equally well. Everywhere, in
, throughout inorganic nature, we have this formative
er, as Fichte would call it—this structural energy
dy to come into play, and build the ultimate par-
es of matter into definite shapes. The ice of our
ters, and of our polar regions, is its handiwork, and
also are the quartz, felspar, and mica of our rocks.
chalk-beds are for the most part composed of minute
lls, which are also the product of structural energy;
behind the shell, as a whole, lies a more remote and
tle formative act. These shells are built up of little
stals of calc-spar, and, to form these crystals, the
uctural force had to deal with the intangible mole-
es of carbonate of lime. This tendency on the part

of matter to organize itself, to grow into shape, to assume definite forms in obedience to the definite action of force, is, as I have said, all-pervading. It is in the ground on which you tread, in the water you drink, in the air you breathe. Incipient life, as it were, manifests itself throughout the whole of what we call inorganic nature.

The forms of the minerals resulting from this play of polar forces are various, and exhibit different degrees of complexity. Men of science avail themselves of all possible means of exploring their molecular architecture. For this purpose they employ in turn, as agents of exploration, light, heat, magnetism, electricity, and sound. Polarized light is especially useful and powerful here. A beam of such light, when sent in among the molecules of a crystal, is acted on by them, and from this action we infer with more or less clearness the manner in which the molecules are arranged. That differences, for example, exist between the inner structure of rock-salt and that of crystallized sugar or sugar-candy is thus strikingly revealed. These actions often display themselves in chromatic phenomena of great splendor, the play of molecular force being so regulated as to cause the removal of some of the colored constituents of white light, while others are left with increased intensity behind.

And now let us pass from what we are accustomed to regard as a dead mineral, to a living grain of corn. When this is examined by polarized light, chromatic phenomena similar to those noticed in crystals are observed. And why? Because the architecture of the grain resembles that of the crystal. In the grain also

e molecules are set in definite positions, and in accordce with their arrangement they act upon the light. it what has built together the molecules of the corn? egarding crystalline architecture, I have already said at you may, if you please, consider the atoms and olecules to be placed in position by a Power external themselves. The same hypothesis is open to you now. it if in the case of crystals you have rejected this non of an external architect, I think you are bound to ect it in the case of the grain, and to conclude that e molecules of the corn, also, are posited by the forces th which they act upon each other. It would be poor ilosophy to invoke an external agent in the one case, d to reject it in the other.

Instead of cutting our grain of corn into slices and bjecting it to the action of polarized light, let us place in the earth, and subject it to a certain degree of rmth. In other words, let the molecules, both of the rn and of the surrounding earth, be kept in that state agitation which we call heat. Under these circumnces, the grain and the substances which surround it eract, and a definite molecular architecture is the relt. A bud is formed; this bud reaches the surface, ere it is exposed to the sun's rays, which are also to regarded as a kind of vibratory motion. And as the otion of common heat, with which the grain and the bstances surrounding it were first endowed, enabled e grain and these substances to exercise their mutual ractions and repulsions, and thus to coalesce in defite forms, so the specific motion of the sun's rays now ables the green bud to feed upon the carbonic acid and e aqueous vapor of the air. The bud appropriates

those constituents of both for which it has an elective attraction, and permits the other constituent to return to the atmosphere. Thus the architecture is carried on. Forces are active at the root, forces are active in the blade, the matter of the air and the matter of the atmosphere are drawn upon, and the plant augments in size. We have in succession the stalk, the ear, the full corn in the ear; the cycle of molecular action being completed by the production of grains, similar to that with which the process began.

Now there is nothing in this process which necessarily eludes the conceptive or imagining power of the human mind. An intellect the same in kind as our own would, if only sufficiently expanded, be able to follow the whole process from beginning to end. It would see every molecule placed in its position by the specific attractions and repulsions exerted between it and other molecules, the whole process, and its consummation, being an instance of the play of molecular force. Given the grain and its environment, with their respective forces, the purely human intellect might, if sufficiently expanded, trace out *à priori* every step of the process of growth, and, by the application of purely mechanical principles, demonstrate that the cycle must end, as it is seen to end, in the reproduction of forms like that with which it began. A necessity rules here, similar to that which rules the planets in their circuits round the sun.

You will notice that I am stating the truth strongly, as at the beginning we agreed it should be stated. But I must go still further, and affirm that in the eye of science the animal body is just as much the product of molecular force as the chalk and the ear of corn, or

crystal of salt or sugar. Many of the parts of the obviously mechanical. Take the human heart, ple, with its system of valves, or take the ex- mechanism of the eye or hand. Animal heat, , is the same in kind as the heat of a fire, be- duced by the same chemical process. Animal too, is as certainly derived from the food of the as the motion of Trevethyck's walking-engine fuel in its furnace. As regards matter, the body creates nothing; as regards force, it creates Which of you by taking thought can add one his stature? All that has been said, then, re- the plant, may be restated with regard to the Every particle that enters into the composition ve, a muscle, or a bone has been placed in its by molecular force. And, unless the existence n these matters be denied, and the element of introduced, we must conclude that, given the of any molecule of the body to its environment, on in the body might be determined mathemat- Our difficulty is not with the *quality* of the prob- with its *complexity*; and this difficulty might be he simple expansion of the faculties we now pos- iven this expansion, with the necessary molecu- and the chick might be deduced as rigorously ogically from the egg as the existence of Neptune disturbances of Uranus, or as conical refraction undulatory theory of light.

see I am not mincing matters, but avowing what many scientific thinkers more or less dis- believe. The formation of a crystal, a plant, or al, is, in their eyes, a purely mechanical prob-

as the crystal of salt or sugar. Many of the parts of the body are obviously mechanical. Take the human heart, for example, with its system of valves, or take the exquisite mechanism of the eye or hand. Animal heat, moreover, is the same in kind as the heat of a fire, being produced by the same chemical process. Animal motion, too, is as certainly derived from the food of the animal as the motion of Trevethyck's walking-engine from the fuel in its furnace. As regards matter, the animal body creates nothing; as regards force, it creates nothing. Which of you by taking thought can add one cubit to his stature? All that has been said, then, regarding the plant, may be restated with regard to the animal. Every particle that enters into the composition of a nerve, a muscle, or a bone has been placed in its position by molecular force. And, unless the existence of law in these matters be denied, and the element of caprice introduced, we must conclude that, given the relation of any molecule of the body to its environment, its position in the body might be determined mathematically. Our difficulty is not with the *quality* of the problem, but with its *complexity;* and this difficulty might be met by the simple expansion of the faculties we now possess. Given this expansion, with the necessary molecular data, and the chick might be deduced as rigorously and as logically from the egg as the existence of Neptune from the disturbances of Uranus, or as conical refraction from the undulatory theory of light.

You see I am not mincing matters, but avowing nakedly what many scientific thinkers more or less distinctly believe. The formation of a crystal, a plant, or an animal, is, in their eyes, a purely mechanical prob-

lem, which differs from the problems of ordinary mech ics, in the smallness of the masses, and the complexity of the processes involved. Here you have one half of our dual truth; let us now glance at the other half. Associated with this wonderful mechanism of the animal body we have phenomena no less certain than those of physics, but between which and the mechanism we discern no necessary connection. A man, for example, can say, "I feel," "I think," "I love"; but how does *consciousness* infuse itself into the problem? The human brain is said to be the organ of thought and feeling: when we are hurt, the brain feels it; when we ponder, or when our passions or affections are excited, it is through the instrumentality of the brain. Let us endeavor to be a little more precise here. I hardly imagine there exists a profound scientific thinker, who has reflected upon the subject, unwilling to admit the extreme probability of the hypothesis, that for every fact of consciousness, whether in the domain of sense, thought, or emotion, a definite molecular condition, of motion or structure, is set up in the brain; or who would be disposed even to deny that if the motion, or structure, be induced by internal causes instead of external, the effect on consciousness will be the same? Let any nerve, for example, be thrown by morbid action into the precise state of motion which would be communicated to it by the pulses of a heated body, surely that nerve will declare itself hot—the mind will accept the subjective intimation exactly as if it were objective. The retina may be excited by purely mechanical means. A blow on the eye causes a luminous flash, and the mere pressure of the finger on the external ball produces a star of light,

which Newton compared to the circles on a peacock's tail. Disease makes people see visions and dream dreams; but, in all such cases, could we examine the organs implicated, we should, on philosophical grounds, expect to find them in that precise molecular condition which the real objects, if present, would superinduce.

The relation of physics to consciousness being thus invariable, it follows that, given the state of the brain, the corresponding thought or feeling might be inferred: or, given the thought or feeling, the corresponding state of the brain might be inferred. But how inferred? It would be at bottom not a case of logical inference at all, but of empirical association. You may reply that many of the inferences of science are of this character—the inference, for example, that an electric current, of a given direction, will deflect a magnetic needle in a definite way. But the cases differ in this, that the passage from the current to the needle, if not demonstrable, is conceivable, and that we entertain no doubt as to the final mechanical solution of the problem. But the passage from the physics of the brain to the corresponding facts of consciousness is inconceivable as a result of mechanics. Granted that a definite thought, and a definite molecular action in the brain, occur simultaneously; we do not possess the intellectual organ, nor apparently any rudiment of the organ, which would enable us to pass, by a process of reasoning, from the one to the other. They appear together, but we do not know why. Were our minds and senses so expanded, strengthened, and illuminated, as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, all their groupings, all their electric discharges, if

uch there be; and were we intimately acquainted with he corresponding states of thought and feeling, we hould be as far as ever from the solution of the probem, "How are these physical processes connected with he facts of consciousness?" The chasm between the wo classes of phenomena would still remain intellectually impassable. Let the consciousness of love, for example, be associated with a right-handed spiral motion of he molecules of the brain, and the consciousness of hate with a left-handed spiral motion. We should then know, when we love, that the motion is in one direction, and, when we hate, that the motion is in the other; but the 'WHY?" would remain as unanswerable as before.

In affirming that the growth of the body is mechancal, and that thought, as exercised by us, has its corelative in the physics of the brain, I think the position of the "Materialist" is stated, as far as that position is tenable one. I think the materialist will be able finally o maintain this position against all attacks; but I do not hink, in the present condition of the human mind, that ie can pass beyond this position. I do not think he is entitled to say that his molecular groupings, and motions, explain everything. In reality they explain nothing. The utmost he can affirm is the association of two classes of phenomena, of whose real bond of union he is in absolute ignorance. The problem of the connection of body and soul is as insoluble, in its modern form, as it was in the pre-scientific ages. Phosphorus is known to enter into the composition of the human brain, and a trenchant German writer has exclaimed, "Ohne Phosphor, kein Gedanke!" That may or may not be the case; but even if we knew it to be the case, the knowledge would not

lighten our darkness. On both sides of the zone here assigned to the materialist he is equally helpless. If you ask him whence is this "Matter" of which we have been discoursing—who or what divided it into molecules, who or what impressed upon them this necessity of running into organic forms—he has no answer. Science is mute in reply to these questions. But if the materialist is confounded and science rendered dumb, who else is prepared with a solution? To whom has this arm of the Lord been revealed? Let us lower our heads, and acknowledge our ignorance, priest and philosopher, one and all.

Perhaps the mystery may resolve itself into knowledge at some future day. The process of things upon this earth has been one of amelioration. It is a long way from the Iguanodon and his contemporaries to the President and Members of the British Association. And whether we regard the improvement from the scientific or from the theological point of view—as the result of progressive development, or of successive exhibitions of creative energy—neither view entitles us to assume that man's present faculties end the series, that the process of amelioration ends with him. A time may therefore come when this ultra-scientific region, by which we are now enfolded, may offer itself to terrestrial, if not to human, investigation. Two-thirds of the rays emitted by the sun fail to arouse the sense of vision. The rays exist, but the visual organ requisite for their translation into light does not exist. And so from this region of darkness and mystery which surrounds us, rays may now be darting which require but the development of the proper intellectual organs to translate them into knowledge as far surpassing ours, as ours surpasses that of the wallowing

eptiles which once held possession of this planet. Meanwhile the mystery is not without its uses. It certainly nay be made a power in the human soul; but it is a ower which has feeling, not knowledge, for its base. It nay be, will be, and I hope is turned to account, both n steadying and strengthening the intellect, and in rescung man from that littleness to which, in the struggle for xistence, or for precedence in the world, he is continally prone.

Musings on the Matterhorn, July 27, 1868

Hacked and hurt by time, the aspect of the mountain rom its higher crags saddened me. Hitherto the impresion it made was that of savage strength; here we had nexorable decay. But this notion of decay implied a eference to a period when the Matterhorn was in the ull strength of mountainhood. Thought naturally ran ack to its remoter origin and sculpture. Nor did hought halt there, but wandered on through molten vorlds to that nebulous haze which philosophers have egarded, and with good reason, as the proximate source f all material things. I tried to look at this universal loud, containing within itself the prediction of all that as since occurred; I tried to imagine it as the seat of hose forces whose action was to issue in solar and stellar ystems, and all that they involve. Did that formless og contain potentially the *sadness* with which I regarded he Matterhorn? Did the *thought* which now ran back to simply return to its primeval home? If so, had we ot better recast our definitions of matter and force; for, life and thought be the very flower of both, any defi-

nition which omits life and thought must be inadequate, if not untrue. Are questions like these warranted? Why not? If the final goal of man has not been yet attained; if his development has not been yet arrested, who can say that such yearnings and questionings are not necessary to the opening of a finer vision, to the budding and the growth of diviner powers? When I look at the heavens and the earth, at my own body, at my strength and weakness, even at these ponderings, and ask myself, Is there no being or thing in the universe that knows more about these matters than I do; what is my answer? Supposing our theologic schemes of creation, condemnation, and redemption to be dissipated; and the warmth of denial which they excite, and which, as a motive force, can match the warmth of affirmation, dissipated at the same time; would the undeflected human mind return to the meridian of absolute neutrality as regards these ultra-physical questions? Is such a position one of stable equilibrium? The channels of thought being already formed, such are the questions, without replies, which could run athwart consciousness during a ten minutes' halt upon the weathered crest of the Matterhorn.

Self-reverence, self-knowledge, self-control,
These three alone lead life to sovereign power.
Yet not for power (power of herself
Would come uncalled for), but to live by law,
Acting the law we live by without fear;
And, because right is right, to follow right
Were wisdom in the scorn of consequence.—TENNYSON.

VII

AN ADDRESS TO STUDENTS[1]

THERE is an idea regarding the nature of man which modern philosophy has sought, and is still seeking, to raise into clearness; the idea, namely, of secular growth. Man is not a thing of yesterday; nor do I imagine that the slightest controversial tinge is imported into this address when I say that he is not a thing of 6,000 years ago. Whether he came originally from stocks or stones, from nebulous gas or solar fire, I know not; if he had any such origin, the process of his transformation is as inscrutable to you and me as that of the grand old legend, according to which "the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul." But, however obscure man's origin may be, his growth is not to be denied. Here a little and there a little added through the ages have slowly transformed him from what he was into what he is. The doctrine has been held that the mind of the child is like a sheet

[1] Delivered at University College, London, Session 1868–69.

of white paper, on which by education we can write what characters we please. This doctrine assuredly needs qualification and correction. In physics, when an external force is applied to a body with a view of affecting its inner texture, if we wish to predict the result, we must know whether the external force conspires with or opposes the internal forces of the body itself; and in bringing the influence of education to bear upon the new-born man his inner powers also must be taken into account. He comes to us as a bundle of inherited capacities and tendencies, labelled "from the indefinite past to the indefinite future"; and he makes his transit from the one to the other through the education of the present time. The object of that education is, or ought to be, to provide wise exercise for his capacities, wise direction for his tendencies, and through this exercise and this direction to furnish his mind with such knowledge as may contribute to the usefulness, the beauty, and the nobleness of his life.

How is this discipline to be secured, this knowledge imparted? Two rival methods now solicit attention—the one organized and equipped, the labor of centuries having been expended in bringing it to its present state of perfection; the other, more or less chaotic, but becoming daily less so, and giving signs of enormous power, both as a source of knowledge and as a means of discipline. These two methods are the classical and the scientific method. I wish they were not rivals; it is only bigotry and short-sightedness that make them so; for assuredly it is possible to give both of them fair play. Though hardly authorized to express an opinion upon the subject, I nevertheless hold the opinion that the proper

study of a language is an intellectual discipline of the highest kind. If I except discussions on the comparative merits of Popery and Protestantism, English grammar was the most important discipline of my boyhood. The piercing through the involved and inverted sentences of "Paradise Lost"; the linking of the verb to its often distant nominative, of the relative to its distant antecedent, of the agent to the object of the transitive verb, of the preposition to the noun or pronoun which it governed, the study of variations in mood and tense, the transpositions often necessary to bring out the true grammatical structure of a sentence—all this was to my young mind a discipline of the highest value, and a source of unflagging delight. How I rejoiced when I found a great author tripping, and was fairly able to pin him to a corner from which there was no escape! As I speak, some of the sentences which exercised me when a boy rise to my recollection. For instance, "He that hath ears to hear, let him hear"; where the "He" is left, as it were, floating in mid-air without any verb to support it. I speak thus of English because it was of real value to me. I do not speak of other languages because their educational value for me was almost insensible. But knowing the value of English so well, I should be the last to deny, or even to doubt, the high discipline involved in the proper study of Latin and Greek.

That study, moreover, has other merits and recommendations. It is, as I have said, organized and systematized by long-continued use. It is an instrument wielded by some of our best intellects in the education of youth; and it can point to results in the achievements of our foremost men. What, then, has science to offer

which is in the least degree likely to compete with such a system? I cannot better reply than by recurring to the grand old story from which I have already quoted. Speaking of the world and all that therein is, of the sky and the stars around it, the ancient writer says, "And God saw all that He had made, and behold it was very good." It is the body of things thus described which science offers to the study of man. There is a very renowned argument much prized and much quoted by theologians, in which the universe is compared to a watch. Let us deal practically with this comparison. Supposing a watch-maker, having completed his instrument, to be so satisfied with his work as to call it very good, what would you understand him to mean? You would not suppose that he referred to the dial-plate in front and the chasing of the case behind, so much as to the wheels and pinions, the springs and jewelled pivots of the works within—to those qualities and powers, in short, which enable the watch to perform its work as a keeper of time. With regard to the knowledge of such a watch he would be a mere ignoramus who would content himself with outward inspection. I do not wish to say one severe word here to-day, but I fear that many of those who are very loud in their praise of the works of the Lord know them only in this outside and superficial way. It is the inner works of the universe which science reverently uncovers; it is the study of these that she recommends as a discipline worthy of all acceptation.

The ultimate problem of physics is to reduce matter by analysis to its lowest condition of divisibility, and force to its simplest manifestations, and then by synthesis to construct from these elements the world as it stands. We

are still a long way from the final solution of this problem; and when the solution comes, it will be more one of spiritual insight than of actual observation. But though we are still a long way from this complete intellectual mastery of nature, we have conquered vast regions of it, have learned their politics and the play of their powers. We live upon a ball of 8,000 miles in diameter, swathed by an atmosphere of unknown height. This ball has been molten by heat, chilled to a solid, and sculptured by water. It is made up of substances possessing distinctive properties and modes of action, which offer problems to the intellect, some profitable to the child, others taxing the highest powers of the philosopher. Our native sphere turns on its axis, and revolves in space. It is one of a band which all do the same. It is illuminated by a sun which, though nearly a hundred millions of miles distant, can be brought virtually into our closets and there subjected to examination. It has its winds and clouds, its rain and frost, its light, heat, sound, electricity, and magnetism. And it has its vast kingdoms of animals and vegetables. To a most amazing extent the human mind has conquered these things, and revealed the logic which runs through them. Were they facts only, without logical relationship, science might, as a means of discipline, suffer in comparison with language. But the whole body of phenomena is instinct with law; the facts are hung on principles, and the value of physical science as a means of discipline consists in the motion of the intellect, both inductively and deductively, along the lines of law marked out by phenomena. As regards the discipline to which I have already referred as derivable from the study of languages—that, and more, is involved in the study of phys-

ical science. Indeed, I believe it would
limit and arrange the study of a porti
to render the mental exercise involved in
tatively the same as that involved in the
language.

I have thus far confined myself to the
ual side of this question. But man is not
he were so, science would, I believe, be
ment. But he feels as well as thinks; h
the sublime and beautiful as well as of th
I believe that even the intellectual actio
man is, consciously or unconsciously, sus
dercurrent of the emotions. It is vain to
arate the moral and emotional from the
a man but observe himself, and he will,
find that, in nine cases out of ten, the em
the motive force which pushes his intel
The reading of the works of two men, ne
bued with the spirit of modern science —
indeed, friendly to that spirit—has placed
These men are the English Carlyle an
Emerson. I must ever gratefully remem
three long cold German winters Carlyle
tub, even when ice was on its surface,

all my consequent intellectual action
this purely moral source. To Carlyl
ought to add Fichte, the greatest rep
idealism. These three unscientific men
tical scientific worker. They called out
ened to the summons, taking the libert
termining for myself the direction w
take.

And I may now cry "Act!" but the
must be yours. I may pull the trigger
not charged there is no result. We
intellectual world as little as in the
remove obstacles, and render latent ca
we cannot suddenly change the nature
birth" itself implies the pre-existence o
requires not to be created but brought
by any amount of missionary labor sud
savage into the civilized Christian. T
man is *secular*—not the work of an hou
though indubitably bound by our org
knows what the potentialities of any hu
requiring only release to be brought into
in the mineral world certain crystals—

plied—the proper word to be spoken to remove a
t, and to render you conscious of light and warm
hin yourselves and sources of both to others.

The circle of human nature, then, is not complete w
the arc of the emotions. The lilies of the field h
value for us beyond their botanical ones—a cert
htening of the heart accompanies the declaration t
olomon in all his glory was not arrayed like one
se." The sound of the village bell has a value bey
acoustical one. The setting sun has a value beyond
ical one. The starry heavens, as you know, had
manuel Kant a value beyond their astronomical
hink it very desirable to keep this horizon of the e
ns open, and not to permit either priest or philoso
draw down his shutters between you and it. Here
d languages, which are sure to be beaten by sci
the purely intellectual fight, have an irresistible cl
ey supplement the work of science by exalting
ining the æsthetic faculty, and must on this account
erished by all who desire to see human culture compl
ere must be a reason for the fascination which th
guages have so long exercised upon powerful and
ted minds—a fascination which will probably conti
men of Greek and Roman mold to the end of tim

which a decision might be based being ab
cipline of suspending the judgment is a c
science, but not so common as it ought t
I walked down Regent Street some time a
of great gifts and acquirements, discussing
ous theological questions. I could not ac
of the origin and destiny of the universe,
pared to enunciate any definite views of
turned to me at length and said, "You su
a theory of the universe." That I should
another have solved this mystery of my
to my friend a matter of course. "I ha
theory of magnetism" was my reply. We
to wait. We ought assuredly to pause befo
the advances of those expounders of the
men, who offer us intellectual peace at t
of intellectual life.

The teachers of the world ought to be its
for the present at all events such men m
trust. By the fulness and freshness of
and utterances they must awaken life in
hopes and terrors which influenced our fath
away, and our trust henceforth must rest
strength of man's moral nature. And her

deal with conceptions which science shu
the illustrator and interpreter of that l

"Jehovah, Jove, or Lord,"

has hitherto filled and strengthened the h

Let me utter one practical word in
care of your health. There have been m
attention to this point might have risen t
might have made great discoveries, writ
commanded armies, or ruled states, but
neglect of this point have come to nothin
cules as oarsman in a rotten boat; what
but by the very force of his stroke expe
his craft? Take care then of the timbe
and avoid all practices likely to introdu
dry rot among them. And this is not to
by desultory or intermittent efforts of the
formation of *habits*. The will no doubt l
put forth its strength in order to crush t
tation. But the formation of right habit
your permanent security. They dimini
of falling when assailed, and they augme
of recovery when overthrown.

If thou would'st know the mystic
Chaunted when the sphere was y
Aloft, abroad, the pean swells,
O wise man hear'st thou half it te
To the open ear it sings
The early genesis of things;
Of tendency through endless ages
Of star-dust and star pilgrimages,
Of rounded worlds, of space and t
Of the old floods' subsiding slime,
Of chemic matter, force and form,
Of poles and powers, cold, wet, an
The rushing metamorphosis
Dissolving all that fixture is,
Melts things that be to things tha
And solid nature to a dream.—Em

Was wär' ein Gott der nur von auss
Im Kreis das All am Finger laufen l
Ihm ziemt's, die Welt im Innern zu
Natur in Sich, Sich in Natur zu heg

VIII

SCIENTIFIC USE OF THE IMAGI

"Lastly, physical investigation, more than anythin us the actual value and right use of the Imagination— which, left to ramble uncontrolled, leads us astray into ties and errors, a land of mists and shadows; but whi experience and reflection, becomes the noblest attribu poetic genius, the instrument of discovery in Science, Newton would never have invented fluxions, nor Da earths and alkalies, nor would Columbus have foun

indirectly the intellect and will, I took wit
works, comprising two volumes of poetry, Go
benlehre," and the work on "Logic" recentl
by Mr. Alexander Bain. In Goethe, so nobl
I chiefly noticed the self-inflicted hurts of g
broke itself in vain against the philosophy
Mr. Bain I found, for the most part, learned a
shining generall; with a dry light, but exhibit
a flush of emotional strength, which prove
logi ians share the common fire of humanity
ested me most when he became the mirror of r
dition. Neither intellectually nor socially is
man to be alone, and the sorrows of though
patiently borne when we find that they hav
perienced by another. From certain pass
book I could infer that Mr. Bain was no stra
sorrows.

Speaking for example of the ebb of intell
which we all from time to time experience
says: "The uncertainty where to look for th
ing of discovery brings the pain of conflict and
of indecision." These words have in them t
of personal experience. The action of the in
periodic. He grapples with a subject of inqu

ditions that I had to equip myself for
ordeal that are now come.

The disciplines of common life are, i
cises in the relations of space, or in the
of bodies in space; and, by such exercises
is, to some extent, prepared for the rec
conceptions. Assuming this preparation
wish gradually grew within me to trac
you to trace, some of the more occult f
tions of Light and Color. I wished, if
you beyond the boundary of mere ob
region where things are intellectually
show you there the hidden mechanism

But how are those hidden things to b
losophers may be right in affirming tha
scend experience: we can, at all events
way from its origin. We can magnify,
and combine experiences, so as to render
poses entirely new. In explaining sen
we habitually form mental images of
There are Tories even in science who re
as a faculty to be feared and avoided
ployed. They have observed its action

tions. Out of the facts of chemistry t
imagination of Dalton formed the atomic
was richly endowed with the imaginative
with Faraday its exercise was incessant,
companying and guiding all his exp
strength and fertility as a discoverer is
in great part to the stimulus of his imag
tific men fight shy of the word becau
scientific connotations; but the fact is, th
exercise of this power, our knowledge c
be a mere tabulation of co-existences and
should still believe in the succession of da
summer and winter; but the conception
vanish from our universe; causal relation
pear, and with them that science which
the parts of nature to an organic whole.

I should like to illustrate by a few
the use that scientific men have already
power of imagination, and to indicate aft
the further uses that they are likely to m
us begin with the rudimentary experience
falling of heavy rain-drops into a tranqu
drop as it strikes the water becomes a ce
ance, from which a series of ring-ripples e

lin's, the *tick* of the drop is heard. N
impulse is propagated, not at the rate of
rate of 4,700 feet a second. In this case i
ity, but the *elasticity* of the water that
Every liquid particle pushed against its
up its motion with extreme rapidity, a
propagated as a thrill. The incompress
as illustrated by the famous Florentine
measure of its elasticity; and to the p
property, in so high a degree, the rapid
a sound-pulse through water is to be asc

But water, as you know, is not nece
duction of sound; air is its most comm
you know that when the air possesses th
sity and elasticity corresponding to th
freezing water, the velocity of sound in
a second. It is almost exactly one-fourt
in water; the reason being that though t
of the water tends to diminish the veloci
molecular elasticity of the liquid far mor
the disadvantage due to weight. By var
we can compel the vibrations of the air
selves; we know the length and frequenc
waves, and we have also obtained great

In the phenomena of sound, we travel
from downright sensible experience. Sti
tion is to some extent exercised. The bo
ample, cannot see the condensations and
the waves of sound. We construct them
we believe as firmly in their existence as
air itself. But now our experience is to b
new region, where a new use is to be made
mastered the cause and mechanism of sour
know the cause and mechanism of light.
tend our inquiries from the auditory to t
There is in the human intellect a power
might almost call it a power of creation—w
into play by the simple brooding upon fac
of the spirit brooding over chaos may ha
experience of this power. In the case now
manifested itself by transplanting into spa
poses of light, an adequately modified form
ism of sound. We know intimately whe
ity of sound depends. When we lessen
the aërial medium, and preserve its elastic
augment the velocity. When we heighten
and keep the density constant, we also aug
ity. A small density, therefore, and a gre

Let us then carry our results from the w
into the world of sense, and see whether
do not issue in the very phenomena of lig
nary knowledge and skilled experiment rev
the multiplied varieties of these phenom
those of the most remote and entangled de
fundamental conception always brings us fa
the truth; if no contradiction to our dedu
be found in external nature, but on all si
and verification; if, moreover, as in the ca
Refraction and in other cases, it actually fo
attention phenomena which no eye had pr
and which no mind had previously imagined
ception must, we think, be something mor
figment of the scientific fancy. In forming
posite and creative power, in which reason
tion are united, has, we believe, led us in
less real than that of the senses, and of w
of sense itself is the suggestion and, to a gr
outcome.

Far be it from me, however, to wish t
movably in this or in any other theoret
With all our belief of it, it will be wel
theory of a luminiferous ether plastic a

anything. What is your warrant for
Simply and solely this: your fellow-c
if they were reasonable; the hypothesis
more, accounts for the facts. To take
ple: you believe that our President is a
Why? There is no known method o
which any one of us can apply himse
any other, so as to demonstrate coincide
possession of reason. If, therefore, yo
dent to be reasonable, it is because he
were reasonable. As in the case of the
"*as if*" you cannot go. Nay, I shoul
close comparison of the data on which l
caused many respectable persons to
ether had the best of it.

This universal medium, this light-et
is the vehicle, not the origin, of wave-m
and transmits, but it does not create.
derive the motions it conveys? For t
luminous bodies. By the motion of a
do not mean its sensible motion, such
candle, or the shooting out of red pro
limb of the sun. I mean an intestine m
or molecules of the luminous body.

ecules accept, without hesitation, the Undulatory
of Light. Like you and me, they one and all bel
an ether and its light-producing waves. Let us
er what this belief involves. Bring your imaginat
e more into play, and figure a series of sound wa
sing through air. Follow them up to their ori
what do you there find? A definite, tangible, vib
body. It may be the vocal chords of a human be
nay be an organ-pipe, or it may be a stretched str
low in the same manner a train of ether-waves to t
rce; remembering at the same time that your ethe
ter, dense, elastic, and capable of motions subject
determined by, mechanical laws. What then do
ect to find as the source of a series of ether-wav
your imagination if it will accept a vibrating
e proportion—a numerical ratio in a state of osc
? I do not think it will. You cannot crown
ice with this abstraction. The scientific imaginat
ch is here authoritative, demands, as the origin
se of a series of ether-waves, a particle of vibra
ter quite as definite, though it may be excessiv
ute, as that which gives origin to a musical sou
h a particle we name an atom or a molecule. I th
intellect, when focused so as to give definition wit

waves generated in the ether by the
luminous bodies are of different lengt
The amplitude is the width of swin
particles of the waves. In water-wave
height of the crest above the trough,
the wave is the horizontal distance be
tive crests. The aggregate of waves
may be broadly divided into two cla
competent, the other incompetent, to
the light-producing waves differ mar
selves in size, form, and force. The le
of these waves is about twice that of t
amplitude of the largest is probably a
of the smallest. Now the force of e
which, expressed with reference to se
intensity of the light, is proportional t
amplitude. Hence, the amplitude bein
the energy of the largest light-givin
ten-thousandfold that of the smallest.
probable. I use these figures not with
ical accuracy, but to give you definite
ences that probably exist among the
And if we take the whole range of
account—its non-visual as well as i

or the sulphide of carbon, all the waves
the smallest ones most. This furnishes
rating the different classes of waves fr
other words, of analyzing the light. S
fracting prism, the waves of the sun a
different degrees from their direct course
violet most. They are virtually pulled
paint upon a white screen placed to
solar spectrum." Strictly speaking,
braces an infinity of colors; but the l
and of our powers of distinction, caus
into seven segments: red, orange, ye
indigo, violet. These are the seven pr
colors.

Separately, or mixed in various pro
waves yield all the colors observed in
ployed in art. Collectively, they give
of whiteness. Pure unsifted solar light
all the wave-constituents of such light
same proportion, the light, though dir
sity, will still be white. The whiteness
sun shining upon it is barely tolerable
same snow under an overcast firmam
Such a firmament enfeebles the light b

It will be understood that the con
would fail if all the waves were dimini
the same absolute quantity. They mu
portionately, instead of equally. If by
tion the waves of red light are split
then, to preserve the light white, the
orange, green, and blue, must also
halves. In short, the reduction must
absolutely equal quantities, but by equ
In white light the preponderance, as
the larger over the smaller waves m
mense. Were the case otherwise, the
blue, of the smaller waves would have
our sensations.

Not only are the waves of ether r
by solids, and by liquids, but when th
air to dense, or from dense air to lig
wave-motion is always reflected. No
changes continually in density from
will help our conceptions if we regard
a series of thin concentric layers, or
shell being of the same density throu
sudden change of density occurring in
to shell. Light would be reflected at t

is dispersed in space. Light thus reflected can refore, be the light of the sky.

But, though the sun's light is not reflected in ion from the aerial layers to the earth, there is itable evidence to show that the light of our firmar cattered light. Proofs of the most cogent descrip ld be here adduced; but we need only consider receive light at the same time from all parts of isphere of heaven. The light of the firmament co us across the direction of the solar rays, and e inst the direction of the solar rays; and this lat opposing rush of wave-motion can only be due to ound of the waves from the air itself, or from sc g suspended in the air. It is also evident that, un action of clouds, the solar light is not reflected by in the proportions which produce white. The blue, which indicates an excess of the shorter wa accounting for the color of the sky, the first ques gested by analogy would undoubtedly be, Is not blue? The blueness of the air has, in fact, been g a solution of the blueness of the sky. But how, if be blue, can the light of sunrise and sunset, w els through vast distances of air, be yellow, ora even red? The passage of white solar light thro

By the scientific use of the imagination
to penetrate this mystery. The cloud ta
size on the part of the waves of ether, bu
all alike. It exercises no selective action.
of this may be that the cloud particles a
comparison with the waves of ether, as to
indifferently. A broad cliff reflects an At
easily as a ripple produced by a seabird's
the presence of large reflecting surfaces, th
ferences of magnitude among the waves
disappear. But supposing the reflecting pa
of being very large, to be very small in co
the size of the waves. In this case, instead
wave being fronted and thrown back, a sma
is shivered off. The great mass of the wa
such a particle without reflection. Scatter,
ful of such minute foreign particles in o
and set imagination to watch their action
waves. Waves of all sizes impinge upon
and you see at every collision a portion of
wave struck off; all the waves of the spec
extreme red to the extreme violet, being th

Remembering that the red waves stan
much in the relation of billows to ripple

A pebble, placed in the way of the ring-ripp
by heavy raindrops on a tranquil pond, will s
fraction of each ripple, while the fractional pa
wave thrown back by the same pebble mig
tesimal. Now we have already made it clear
that to preserve the solar light white its con
portions must not be altered; but in the ac
performed by these very small particles the
are altered; an undue fraction of the smaller w
tered by the particles, and, as a consequence
tered light, blue will be the predominant
other colors of the spectrum must, to som
associated with the blue. They are not abs
cient. We ought, in fact, to have them all,
ishing proportions, from the violet to the red

We have here presented a case to the imag
assuming the undulatory theory to be a reali
I think, fairly reasoned our way to the con
were particles, small in comparison to the size
waves, sown in our atmosphere, the light
those particles would be exactly such as w
our azure skies. When this light is analy
colors of the spectrum are found, and they
the proportions indicated by our conclusion.

appear yellowish. But as the sun sinks
zon the atmospheric distances increase, an
the number of the scattering particles. T
succession the violet, the indigo, the blue
turb the proportions of green. The trans
der such circumstances must pass from
orange to red. This also is exactly what
ure. Thus, while the reflected light gives
deep azure of the Alpine skies, the transm
us at sunset the warm crimson of the Alpi
phenomena certainly occur *as if* our atm
medium rendered slightly turbid by the
pension of exceedingly small foreign parti

Here, as before, we encounter our sc
It is one of the parasites of science, eve
ready to plant itself and sprout, if it ca
points of our philosophy. But a strong co
the parasite, and in our case, as we qu
nomena, probability grows like growing
the end the malady of doubt is comple
The first question that naturally arises is
particles be really proved to act in the ma
No doubt of it. Each one of you can subm
to an experimental test. Water will not
but spirit will dissolve it; and when spi

gram of clean mastic is dissolved in eighty
of absolute alcohol, and the transparent solut
to drop into a beaker containing clear water,
stirred. An exceedingly fine precipitate is
which declares its presence by its action
Placing a dark surface behind the beaker, a
the light to fall into it from the top or front
is seen to be distinctly blue. It is not perha
a blue as may be seen on exceptional day
Alps, but it is a very fair sky-blue. A trac
water gives a tint of blue. London, and
pool, milk makes an approximation to the
through the operation of the same cause; a
has irreverently disclosed the fact that the
eye is simply a turbid medium.

The action of turbid media upon light w
by Goethe, who, though unacquainted with th
theory, was led by his experiments to rega
ment as an illuminated turbid medium, with
of space behind it. He describes glasses sho
yellow by transmitted, and a beautiful blue
light. Professor Stokes, who was probably th
cern the real nature of the action of small pa

tal specimens of such glass are to be foun
St. James's Street. What artists call "
an effect of this description. Through
nute particles, the browns of a picture
appearance of the bloom of a plum. By
nish with a silk handkerchief optical c
lished and the chill disappears. Some
nessed Mr. Hirst experimenting at Zerm
water of the Visp. When kept still fo
grosser matter sank, but the finer parti
pended, and gave a distinctly blue ti
The blueness of certain Alpine lakes h
be in part due to this cause. Professor I
several striking cases of a similar kin
markable paper the late Principal Fo
steam issuing from the safety-valve of a
favorably observed, exhibits at a certain
densation the colors of the sky. It is
light, and orange or red by transmitted
effect, as pointed out by Goethe, is to
hibited by peat-smoke. More than ten y
myself by observing, on a calm day
straight smoke-columns rising from th
It was easy to project the lower po

precipitate, you may render the white lig
ruby-colored as the sun, when seen thro
smoke, or upon Alpine horizons. I do
point to the gross smoke arising from coal
tion of the action of small particles, becau
soon absorbs and destroys the waves of b
sending them to the eyes of the observer.

These multifarious facts, and numberles
cannot now be referred to, are explained
the single principle that, where the scatteri
small in comparison to the ethereal waves,
reflected light a greater proportion of the
and in the transmitted light a greater pr
larger waves, than existed in the origin
The consequence, as regards sensation, is
case blue is predominant, and in the other
Our best microscopes can readily reveal o
than $\frac{1}{50000}$th of an inch in diameter. This
length of a wave of red light. Indeed a
scope would enable us to discern objects n
diameter the length of the smallest waves
spectrum.[1] By the microscope, therefore,
particles. If they be as large as the light-
infallibly be seen; and if they be not so

detection. But no particles were see
scope the turbid liquid was not to
distilled water.[1]

But we have it in our power
closely than we have hitherto done,
of this problem. We can generate,
and prove their perfect identity wit
regards the exhibition of a number
phenomena. By a continuous proc
over, we are able to connect sky-ma
term, with molecular matter on th
molar matter, or matter in sensible
In illustration of this, I will take an
by some of my own researches, and
ren of Marseilles at the Exeter meet
sociation. Sulphur and oxygen com
ous acid gas, two atoms of oxygen
constituting the molecule of sulphur
recently shown that waves of ether
source, such as the sun or the electr
to shake asunder the atoms of ga
chemist would call this "decomposit
behooves us, who are examining th
of the imagination, to keep constant

eye. Thus, without solution of continuity, we start with matter in the atom, and end with matter in the mass; sky-matter being the middle term of the series of transformations.

Instead of sulphurous acid, we might choose a dozen other substances, and produce the same effect with all of them. In the case of some—probably in the case of all—it is possible to preserve matter in the firmamental condition for fifteen or twenty minutes under the continual operation of the light. During these fifteen or twenty minutes the particles constantly grow larger, without ever exceeding the size requisite to the production of the celestial blue. Now when two vessels are placed before us, each containing sky-matter, it is possible to state with great distinctness which vessel contains the largest particles. The eye is very sensitive to differences of light, when, as in our experiments, it is placed in comparative darkness, and the wave-motion thrown against the retina is small. The larger particles declare themselves by the greater whiteness of their scattered light. Call now to mind the observation, or effort at observation, made by our President, when he failed to distinguish the particles of mastic in Brucke's medium, and when you have done this, please follow me. A beam of light is permitted to act upon a certain vapor. In two minutes the azure appears, but at the end of fifteen minutes it has not ceased to be azure. After fifteen minutes its color, and some other phenomena, pronounce it to be a blue of distinctly smaller particles than those sought for in vain by Mr. Huxley. These particles, as already stated, must have been less than $\frac{1}{100000}$th of an inch in diameter. And now I want you to consider the following question: Here are

particles which have been growing continually for fifteen minutes, and at the end of that time are demonstrably smaller than those which defied the microscope of Mr. Huxley—*What must have been the size of these particles at the beginning of their growth?* What notion can you form of the magnitude of such particles? The distances of stellar space give us simply a bewildering sense of vastness, without leaving any distinct impression on the mind; and the magnitudes with which we have here to do bewilder us equally in the opposite direction. We are dealing with infinitesimals, compared with which the test objects of the microscope are literally immense.

Small in mass, the vastness in point of number of the particles of our sky may be inferred from the continuity of its light. It is not in broken patches, nor at scattered points, that the heavenly azure is revealed. To the observer on the summit of Mont Blanc, the blue is as uniform and coherent as if it formed the surface of the most close-grained solid. A marble dome would not exhibit a stricter continuity. And Mr. Glaisher will inform you, that if our hypothetical shell were lifted to twice the height of Mont Blanc above the earth's surface, we should still have the azure overhead. By day this light quenches the stars; even by moonlight it is able to exclude from vision all stars between the fifth and the eleventh magnitude. It may be likened to a noise, and the feebler stellar radiance to a whisper drowned by the noise.

What is the nature of the particles which shed this light? The celebrated De la Rive ascribes the haze of the Alps in fine weather to floating organic germs. Now the possible existence of germs in such profusion has been held up as an absurdity. It has been affirmed that they

would darken the air, and on the assumed impossibility of their existence in the requisite numbers, without invasion of the solar light, an apparently powerful argument has been based by believers in spontaneous generation. Similar arguments have been used by the opponents of the germ theory of epidemic disease, who have triumphantly challenged an appeal to the microscope and the chemist's balance to decide the question. Such arguments, however, are founded on a defective acquaintance with the powers and properties of matter. Without committing myself in the least to De la Rive's notion, to the doctrine of spontaneous generation, or to the germ theory of disease, I would simply draw attention to the demonstrable fact that, in the atmosphere, we have particles which defy both the microscope and the balance, which do not darken the air, and which exist, nevertheless, in multitudes sufficient to reduce to insignificance the Israelitish hyperbole regarding the sands upon the sea-shore.

The varying judgments of men on these and other questions may perhaps be, to some extent, accounted for by that doctrine of Relativity which plays so important a part in philosophy. This doctrine affirms that the impressions made upon us by any circumstance, or combination of circumstances, depend upon our previous state. Two travellers upon the same height, the one having ascended to it from the plain, the other having descended to it from a higher elevation, will be differently affected by the scene around them. To the one nature is expanding, to the other it is contracting, and impressions which have two such different antecedent states are sure to differ. In our scientific judgments the law of relativity may also

play an important part. To two men, one educated in the school of the senses, having mainly occupied himself with observation; the other educated in the school of imagination as well, and exercised in the conceptions of atoms and molecules to which we have so frequently referred, a bit of matter, say $\frac{1}{5000}$th of an inch in diameter, will present itself differently. The one descends to it from his molar heights, the other climbs to it from his molecular lowlands. To the one it appears small, to the other large. So, also, as regards the appreciation of the most minute forms of life revealed by the microscope. To one of the men these naturally appear conterminous with the ultimate particles of matter; there is but a step from the atom to the organism. The other discerns numberless organic gradations between both. Compared with his atoms, the smallest vibrios and bacteria of the microscopic field are as behemoth and leviathan. The law of relativity may to some extent explain the different attitudes of two such persons with regard to the question of spontaneous generation. An amount of evidence which satisfies the one entirely fails to satisfy the other; and while to the one the last bold defence and startling expansion of the doctrine by Dr. Bastian will appear perfectly conclusive, to the other it will present itself as merely imposing a labor of demolition on subsequent investigators.[1]

Let me say here that many of our physiological observers appear to form a very inadequate estimate of the distance which separates the microscopic from the molecular limit, and that, as a consequence, they sometimes

[1] When these words were uttered I did not imagine that the chief labor of demolition would fall upon myself. 1878.

employ a phraseology calculated to mislead. When, for example, the contents of a cell are described as perfectly homogeneous or as absolutely structureless, because the microscope fails to discover any structure; or when two structures are pronounced to be without difference, because the microscope can discover none, then, I think, the microscope begins to play a mischievous part. A little consideration will make it plain that the microscope can have no voice in the question of germ structure. Distilled water is more perfectly homogeneous than any possible organic germ. What is it that causes the liquid to cease contracting at 39° Fahr., and to expand until it freezes? We have here a structural process of which the microscope can take no note, nor is it likely to do so by any conceivable extension of its powers. Place distilled water in the field of an electro-magnet, and bring a microscope to bear upon it. Will any change be observed when the magnet is excited? Absolutely none; and still profound and complex changes have occurred. First of all, the particles of water have been rendered diamagnetically polar; and secondly, in virtue of the structure impressed upon it by the magnetic whirl of its molecules, the liquid twists a ray of light in a fashion perfectly determinate both as to quantity and direction.

Have the diamond, the amethyst, and the countless other crystals formed in the laboratories of nature and of man no structure? Assuredly they have; but what can the microscope make of it? Nothing. It cannot be too distinctly borne in mind that between the microscopic limit, and the true molecular limit, there is room for infinite permutations and combinations. It is in this region that the poles of the atoms are arranged, that tendency is given

to their powers; so that when these poles and powers have free action, proper stimulus, and a suitable environment, they determine, first the germ, and afterward the complete organism. This first marshalling of the atoms, on which all subsequent action depends, baffles a keener power than that of the microscope. When duly pondered, the complexity of the problem raises the doubt, not of the power of our instrument, for that is *nil*, but whether we ourselves possess the intellectual elements which will ever enable us to grapple with the ultimate structural energies of nature.[1]

In more senses than one Mr. Darwin has drawn heavily upon the scientific tolerance of his age. He has drawn heavily upon time in his development of species, and he has drawn adventurously upon matter in his theory of pangenesis. According to this theory, a germ, already microscopic, is a world of minor germs. Not only is the organism as a whole wrapped up in the germ, but every organ of the organism has there its special seed. This, I say, is an adventurous draft on the power of matter to divide itself and distribute its forces. But, unless we are perfectly sure that he is overstepping the bounds of reason, that he is unwittingly sinning against observed fact or demonstrated law—for a mind like that of Darwin can never sin wittingly against either fact or law—we ought,

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[1] "In using the expression 'one sort of living substance' I must guard against being supposed to mean that any kind of living protoplasm is homogeneous. Hyaline though it may appear, we are not at present able to assign any limit to its complexity of structure."—Burdon Sanderson, in the "British Medical Journal," January 16, 1875.

We have here scientific insight, and its correlative caution. In fact Dr. Sanderson's important researches are a continued illustration of the position laid down above.

I think, to be cautious in limiting his intellectual horizon. If there be the least doubt in the matter, it ought to be given in favor of the freedom of such a mind. To it a vast possibility is in itself a dynamic power, though the possibility may never be drawn upon. It gives me pleasure to think that the facts and reasonings of this discourse tend rather toward the justification of Mr. Darwin, than toward his condemnation; for they seem to show the perfect competence of matter and force, as regards divisibility and distribution, to bear the heaviest strain that he has hitherto imposed upon them.

In the case of Mr. Darwin, observation, imagination, and reason combined have run back with wonderful sagacity and success over a certain length of the line of biological succession. Guided by analogy, in his "Origin of Species" he placed at the root of life a primordial germ, from which he conceived the amazing variety of the organisms now upon the earth's surface might be deduced. If this hypothesis were even true, it would not be final. The human mind would infallibly look behind the germ, and however hopeless the attempt, would inquire into the history of its genesis. In this dim twilight of conjecture the searcher welcomes every gleam, and seeks to augment his light by indirect incidences. He studies the methods of nature in the ages and the worlds within his reach, in order to shape the course of speculation in antecedent ages and worlds. And though the certainty possessed by experimental inquiry is here shut out, we are not left entirely without guidance. From the examination of the solar system, Kant and Laplace came to the conclusion that its various bodies once formed parts of the same undislocated mass; that matter in a nebulous form preceded matter in

its present form; that as the ages rolled away, heat was wasted, condensation followed, planets were detached; and that finally the chief portion of the hot cloud reached, by self-compression, the magnitude and density of our sun. The earth itself offers evidence of a fiery origin; and in our day the hypothesis of Kant and Laplace receives the independent countenance of spectrum analysis, which proves the same substances to be common to the earth and sun.

Accepting some such view of the construction of our system as probable, a desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. On its first detachment from the central mass, life, as we understand it, could not have been present on the earth. How, then, did it come there? The thing to be encouraged here is a reverent freedom—a freedom preceded by the hard discipline which checks licentiousness in speculation—while the thing to be repressed, both in science and out of it, is dogmatism. And here I am in the hands of the meeting—willing to end, but ready to go on. I have no right to intrude upon you, unasked, the unformed notions which are floating like clouds, or gathering to more solid consistency, in the modern speculative scientific mind. But if you wish me to speak plainly, honestly and undisputatiously, I am willing to do so. On the present occasion—

You are ordained to call, and I to come.

Well, your answer is given, and I obey your call.

Two or three years ago, in an ancient London college, I listened to a discussion at the end of a lecture by a very

remarkable man. Three or four hundred clergymen were present at the lecture. The orator began with the civilization of Egypt in the time of Joseph; pointing out the very perfect organization of the kingdom, and the possession of chariots, in one of which Joseph rode, as proving a long antecedent period of civilization. He then passed on to the mud of the Nile, its rate of augmentation, its present thickness, and the remains of human handiwork found therein; thence to the rocks which bound the Nile valley, and which teem with organic remains. Thus in his own clear way he caused the idea of the world's age to expand itself indefinitely before the minds of his audience, and he contrasted this with the age usually assigned to the world. During his discourse he seemed to be swimming against a stream, he manifestly thought that he was opposing a general conviction. He expected resistance in the subsequent discussion; so did I. But it was all a mistake; there was no adverse current, no opposing conviction, no resistance; merely here and there a half-humorous but unsuccessful attempt to entangle him in his talk. The meeting agreed with all that had been said regarding the antiquity of the earth and of its life. They had, indeed, known it all long ago, and they rallied the lecturer for coming among them with so stale a story. It was quite plain that this large body of clergymen, who were, I should say, to be ranked among the finest samples of their class, had entirely given up the ancient landmarks, and transported the conception of life's origin to an indefinitely distant past.

This leads us to the gist of our present inquiry, which is this: Does life belong to what we call matter, or is it an independent principle inserted into matter at some suit-

able epoch—say when the physical conditions became such as to permit of the development of life? Let us put the question with the reverence due to a faith and culture in which we all were cradled, and which are the undeniable historic antecedents of our present enlightenment. I say, let us put the question reverently, but let us also put it clearly and definitely. There are the strongest grounds for believing that during a certain period of its history the earth was not, nor was it fit to be, the theatre of life. Whether this was ever a nebulous period, or merely a molten period, does not signify much; and if we revert to the nebulous condition, it is because the probabilities are really on its side. Our question is this: Did creative energy pause until the nebulous matter had condensed, until the earth had been detached, until the solar fire had so far withdrawn from the earth's vicinity as to permit a crust to gather round the planet? Did it wait until the air was isolated; until the seas were formed; until evaporation, condensation, and the descent of rain had begun; until the eroding forces of the atmosphere had weathered and decomposed the molten rocks so as to form soils; until the sun's rays had become so tempered by distance, and by waste, as to be chemically fit for the decompositions necessary to vegetable life? Having waited through these eons until the proper conditions had set in, did it send the fiat forth, "Let there be Life!"? These questions define a hypothesis not without its difficulties, but the dignity of which in relation to the world's knowledge was demonstrated by the nobleness of the men whom it sustained.

Modern scientific thought is called upon to decide between this hypothesis and another; and public thought

generally will afterward be called upon to do the same. But, however the convictions of individuals here and there may be influenced, the process must be slow and secular which commends the hypothesis of Natural Evolution to the public mind. For what are the core and essence of this hypothesis? Strip it naked, and you stand face to face with the notion that not alone the more ignoble forms of animalcular or animal life, not alone the nobler forms of the horse and lion, not alone the exquisite and wonderful mechanism of the human body, but that the human mind itself—emotion, intellect, will, and all their phenomena—were once latent in a fiery cloud. Surely the mere statement of such a notion is more than a refutation. But the hypothesis would probably go even further than this. Many who hold it would probably assent to the position that, at the present moment, all our philosophy, all our poetry, all our science, and all our art—Plato, Shakespeare, Newton, and Raphael—are potential in the fires of the sun. We long to learn something of our origin. If the Evolution hypothesis be correct, even this unsatisfied yearning must have come to us across the ages which separate the primeval mist from the consciousness of to-day. I do not think that any holder of the Evolution hypothesis would say that I overstate or overstrain it in any way. I merely strip it of all vagueness, and bring before you, unclothed and unvarnished, the notions by which it must stand or fall.

Surely these notions represent an absurdity too monstrous to be entertained by any sane mind. But why are such notions absurd, and why should sanity reject them? The law of Relativity, of which we have previously spoken, may find its application here. These Evolution

notions are absurd, monstrous, and fit only for the intellectual gibbet, in relation to the ideas concerning matter which were drilled into us when young. Spirit and matter have ever been presented to us in the rudest contrast, the one as all-noble, the other as all-vile. But is this correct? Upon the answer to this question all depends. Supposing that, instead of having the foregoing antithesis of spirit and matter presented to our youthful minds, we had been taught to regard them as equally worthy, and equally wonderful; to consider them, in fact, as two opposite faces of the self-same mystery. Supposing that in youth we had been impregnated with the notion of the poet Goethe, instead of the notion of the poet Young, and taught to look upon matter, not as "brute matter," but as the "living garment of God"; do you not think that under these altered circumstances the law of Relativity might have had an outcome different from its present one? Is it not probable that our repugnance to the idea of primeval union between spirit and matter might be considerably abated? Without this total revolution of the notions now prevalent, the Evolution hypothesis must stand condemned; but in many profoundly thoughtful minds such a revolution has already taken place. They degrade neither member of the mysterious duality referred to; but they exalt one of them from its abasement, and repeal the divorce hitherto existing between them. In substance, if not in words, their position as regards the relation of spirit and matter is: "What God hath joined together, let no man put asunder."

You have been thus led to the outer rim of speculative science, for beyond the nebulæ scientific thought has never hitherto ventured. I have tried to state that which I con-

sidered ought, in fairness, to be outspoken. I neither think this Evolution hypothesis is to be flouted away contemptuously, nor that it ought to be denounced as wicked. It is to be brought before the bar of disciplined reason, and there justified or condemned. Let us hearken to those who wisely support it, and to those who wisely oppose it; and let us tolerate those, whose name is legion, who try foolishly to do either of these things. The only thing out of place in the discussion is dogmatism on either side. Fear not the Evolution hypothesis. Steady yourselves, in its presence, upon that faith in the ultimate triumph of truth which was expressed by old Gamaliel when he said: "If it be of God, ye cannot overthrow it; if it be of man, it will come to naught." Under the fierce light of scientific inquiry, it is sure to be dissipated if it possess not a core of truth. Trust me, its existence as a hypothesis is quite compatible with the simultaneous existence of all those virtues to which the term "Christian" has been applied. It does not solve—it does not profess to solve—the ultimate mystery of this universe. It leaves, in fact, that mystery untouched. For, granting the nebula and its potential life, the question, whence they came, would still remain to baffle and bewilder us. At bottom, the hypothesis does nothing more than "transport the conception of life's origin to an indefinitely distant past."

Those who hold the doctrine of Evolution are by no means ignorant of the uncertainty of their data, and they only yield to it a provisional assent. They regard the nebular hypothesis as probable, and, in the utter absence of any evidence to prove the act illegal, they extend the method of nature from the present into the past. Here

he observed uniformity of nature is their only guide. Within the long range of physical inquiry, they have never discerned in nature the insertion of caprice. Throughout this range, the laws of physical and intellectual continuity have run side by side. Having thus determined the elements of their curve in a world of observation and experiment, they prolong that curve into an antecedent world, and accept as probable the unbroken sequence of development from the nebula to the present time. You never hear the really philosophical defenders of the doctrine of Uniformity speaking of *impossibilities* in nature. They never say, what they are constantly charged with saying, that it is impossible for the Builder of the universe to alter His work. Their business is not with the possible, but the actual—not with a world which *might* be, but with a world that *is*. This they explore with a courage not unmixed with reverence, and according to methods which, like the quality of a tree, are tested by their fruits. They have but one desire—to know the truth. They have but one fear—to believe a lie. And if they know the strength of science, and rely upon it with unswerving trust, they also know the limits beyond which science ceases to be strong. They best know that questions offer themselves to thought, which science, as now prosecuted, has not even the tendency to solve. They have as little fellowship with the atheist who says there is no God, as with the theist who professes to know the mind of God. "Two things," said Immanuel Kant, "fill me with awe: the starry heavens, and the sense of moral responsibility in man." And in his hours of health and strength and sanity, when the stroke of action has ceased, and the pause of reflection has set in, the scientific in-

vestigator finds himself overshadowed by the same awe. Breaking contact with the hampering details of earth, it associates him with a Power which gives fulness and tone to his existence, but which he can neither analyze nor comprehend.

not from the study of nature, but from what lay much closer to them—the observation of men. Their theories accordingly took an anthropomorphic form. To supersensual beings, which, "however potent and invisible, were nothing but a species of human creatures, perhaps raised from among mankind, and retaining all human passions and appetites,"[1] were handed over the rule and governance of natural phenomena.

Tested by observation and reflection, these early notions failed in the long run to satisfy the more penetrating intellects of our race. Far in the depths of history we find men of exceptional power differentiating themselves from the crowd, rejecting these anthropomorphic notions, and seeking to connect natural phenomena with their physical principles. But, long prior to these purer efforts of the understanding, the merchant had been abroad, and rendered the philosopher possible; commerce had been developed, wealth amassed, leisure for travel and speculation secured, while races educated under different conditions, and therefore differently informed and endowed, had been stimulated and sharpened by mutual contact. In those regions where the commercial aristocracy of ancient Greece mingled with their Eastern neighbors, the sciences were born, being nurtured and developed by free-thinking and courageous men. The state of things to be displaced may be gathered from a passage of Euripides quoted by Hume. "There is nothing in the world; no glory, no prosperity. The gods toss all into confusion; mix everything with its reverse, that all of us, from our ignorance and uncertainty, may pay them the more wor-

[1] Hume, "Natural History of Religion."

ship and reverence." Now as science demands the radical extirpation of caprice, and the absolute reliance upon law in nature, there grew, with the growth of scientific notions, a desire and determination to sweep from the field of theory this mob of gods and demons, and to place natural phenomena on a basis more congruent with themselves.

The problem which had been previously approached from above was now attacked from below; theoretic effort passed from the super- to the sub-sensible. It was felt that to construct the universe in idea it was necessary to have some notion of its constituent parts—of what Lucretius subsequently called the "First Beginnings." Abstracting again from experience, the leaders of scientific speculation reached at length the pregnant doctrine of atoms and molecules, the latest developments of which were set forth with such power and clearness at the last meeting of the British Association. Thought, no doubt, had long hovered about this doctrine before it attained the precision and completeness which it assumed in the mind of Democritus,[1] a philosopher who may well for a moment arrest our attention. "Few great men," says Lange, a non-materialist, in his excellent "History of Materialism," to the spirit and to the letter of which I am equally indebted, "have been so despitefully used by history as Democritus. In the distorted images sent down to us through unscientific traditions, there remains of him almost nothing but the name of 'the laughing philosopher,' while figures of immeasurably smaller significance spread themselves out at full length before us." Lange

[1] Born 460 B.C.

speaks of Bacon's high appreciation of Democritus—for ample illustrations of which I am indebted to my excellent friend Mr. Spedding, the learned editor and biographer of Bacon. It is evident, indeed, that Bacon considered Democritus to be a man of weightier metal than either Plato or Aristotle, though their philosophy "was noised and celebrated in the schools, amid the din and pomp of professors." It was not they, but Genseric and Attila and the barbarians, who destroyed the atomic philosophy. "For, at a time when all human learning had suffered shipwreck, these planks of Aristotelian and Platonic philosophy, as being of a lighter and more inflated substance, were preserved and came down to us, while things more solid sank and almost passed into oblivion."

The son of a wealthy father, Democritus devoted the whole of his inherited fortune to the culture of his mind. He travelled everywhere; visited Athens when Socrates and Plato were there, but quitted the city without making himself known. Indeed, the dialectic strife in which Socrates so much delighted had no charm for Democritus, who held that "the man who readily contradicts, and uses many words, is unfit to learn anything truly right." He is said to have discovered and educated Protagoras the Sophist, being struck as much by the manner in which he, being a hewer of wood, tied up his fagots, as by the sagacity of his conversation. Democritus returned poor from his travels, was supported by his brother, and at length wrote his great work entitled "Diakosmos," which he read publicly before the people of his native town. He was honored by his countrymen in various ways, and died serenely at a great age.

The principles enunciated by Democritus reveal his un-

compromising antagonism to those who deduced the phenomena of nature from the caprices of the gods. They are briefly these: 1. From nothing comes nothing. Nothing that exists can be destroyed. All changes are due to the combination and separation of molecules. 2. Nothing happens by chance; every occurrence has its cause, from which it follows by necessity. 3. The only existing things are the atoms and empty space; all else is mere opinion. 4. The atoms are infinite in number and infinitely various in form; they strike together, and the lateral motions and whirlings which thus arise are the beginnings of worlds. 5. The varieties of all things depend upon the varieties of their atoms, in number, size, and aggregation. 6. The soul consists of fine, smooth, round atoms, like those of fire. These are the most mobile of all: they interpenetrate the whole body, and in their motions the phenomena of life arise.

The first five propositions are a fair general statement of the atomic philosophy, as now held. As regards the sixth, Democritus made his finer atoms do duty for the nervous system, whose functions were then unknown. The atoms of Democritus are individually without sensation; they combine in obedience to mechanical laws; and not only organic forms, but the phenomena of sensation and thought, are the result of their combination.

That great enigma, "the exquisite adaptation of one part of an organism to another part, and to the conditions of life," more especially the construction of the human body, Democritus made no attempt to solve. Empedocles, a man of more fiery and poetic nature, introduced the notion of love and hate among the atoms, to account for their combination and separation; and bolder than De-

mocritus, he struck in with the penetrating thought, linked, however, with some wild speculation, that it lay in the very nature of those combinations which were suited to their ends (in other words, in harmony with their environment) to maintain themselves, while unfit combinations, having no proper habitat, must rapidly disappear. Thus, more than 2,000 years ago, the doctrine of the "survival of the fittest," which in our day, not on the basis of vague conjecture, but of positive knowledge, has been raised to such extraordinary significance, had received at all events partial enunciation.[1]

Epicurus,[2] said to be the son of a poor schoolmaster at Samos, is the next dominant figure in the history of the atomic philosophy. He mastered the writings of Democritus, heard lectures in Athens, went back to Samos, and subsequently wandered through various countries. He finally returned to Athens, where he bought a garden, and surrounded himself by pupils, in the midst of whom he lived a pure and serene life, and died a peaceful death. Democritus looked to the soul as the ennobling part of man; even beauty, without understanding, partook of animalism. Epicurus also rated the spirit above the body; the pleasure of the body being that of the moment, while the spirit could draw upon the future and the past. His philosophy was almost identical with that of Democritus; but he never quoted either friend or foe. One main object of Epicurus was to free the world from superstition and the fear of death. Death he treated with indifference. It merely robs us of sensation. As long as we are, death is not; and when death is, we are not. Life has no more

[1] See "Lange," 2d edit., p. 23.

[2] Born 342 B.C.

evil for him who has made up his mind that it is no evil not to live. He adored the gods, but not in the ordinary fashion. The idea of Divine power, properly purified, he thought an elevating one. Still he taught, "Not he is godless who rejects the gods of the crowd, but rather he who accepts them." The gods were to him eternal and immortal beings, whose blessedness excluded every thought of care or occupation of any kind. Nature pursues her course in accordance with everlasting laws, the gods never interfering. They haunt

> The lucid interspace of world and world
> Where never creeps a cloud or moves a wind,
> Nor ever falls the least white star of snow,
> Nor ever lowest roll of thunder moans,
> Nor sound of human sorrow mounts to mar
> Their sacred everlasting calm.[1]

Lange considers the relation of Epicurus to the gods subjective; the indication, probably, of an ethical requirement of his own nature. We cannot read history with open eyes, or study human nature to its depths, and fail to discern such a requirement. Man never has been, and he never will be, satisfied with the operations and products of the Understanding alone; hence physical science cannot cover all the demands of his nature. But the history of the efforts made to satisfy these demands might be broadly described as a history of errors—the error, in great part, consisting in ascribing fixity to that which is fluent, which varies as we vary, being gross when we are gross, and becoming, as our capacities widen, more abstract and sublime. On one great point the mind of Epi-

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[1] Tennyson's "Lucretius."

curus was at peace. He neither sought nor expected, here or hereafter, any personal profit from his relation to the gods. And it is assuredly a fact that loftiness and serenity of thought may be promoted by conceptions which involve no idea of profit of this kind. "Did I not believe," said a great man[1] to me once, "that an Intelligence is at the heart of things, my life on earth would be intolerable." The utterer of these words is not, in my opinion, rendered less, but more, noble by the fact that it was the need of ethical harmony here, and not the thought of personal happiness hereafter, that prompted his observation.

There are persons, not belonging to the highest intellectual zone, nor yet to the lowest, to whom perfect clearness of exposition suggests want of depth. They find comfort and edification in an abstract and learned phraseology. To such people Epicurus, who spared no pains to rid his style of every trace of haze and turbidity, appeared, on this very account, superficial. He had, however, a disciple who thought it no unworthy occupation to spend his days and nights in the effort to reach the clearness of his master, and to whom the Greek philosopher is mainly indebted for the extension and perpetuation of his fame. Some two centuries after the death of Epicurus, Lucretius[2] wrote his great poem, "On the Nature of Things," in which he, a Roman, developed with extraordinary ardor the philosophy of his Greek predecessor. He wishes to win over his friend Memmius to the school of Epicurus; and although he has no rewards in a future life to offer, although his object appears to be a purely negative one, he addresses his friend with the heat of an

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[1] Carlyle.

[2] Born 99 B.C.

apostle. His object, like that of his great forerunner, is the destruction of superstition; and considering that men in his day trembled before every natural event as a direct monition from the gods, and that everlasting torture was also in prospect, the freedom aimed at by Lucretius might be deemed a positive good. "This terror," he says, "and darkness of mind, must be dispelled, not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature." He refutes the notion that anything can come out of nothing, or that what is once begotten can be recalled to nothing. The first beginnings, the atoms, are indestructible, and into them all things can be resolved at last. Bodies are partly atoms and partly combinations of atoms; but the atoms nothing can quench. They are strong in solid singleness, and, by their denser combination, all things can be closely packed and exhibit enduring strength. He denies that matter is infinitely divisible. We come at length to the atoms, without which, as an imperishable substratum, all order in the generation and development of things would be destroyed.

The mechanical shock of the atoms being, in his view, the all-sufficient cause of things, he combats the notion that the constitution of nature has been in any way determined by intelligent design. The interaction of the atoms throughout infinite time rendered all manner of combinations possible. Of these, the fit ones persisted, while the unfit ones disappeared. Not after sage deliberation did the atoms station themselves in their right places, nor did they bargain what motions they should assume. From all eternity they have been driven together, and, after trying motions and unions of every kind, they fell at length into the arrangements out of which this system of things has

been evolved. "If you will apprehend and keep in mind these things, Nature, free at once, and rid of her haughty lords, is seen to do all things spontaneously of herself, without the meddling of the gods."[1]

To meet the objection that his atoms cannot be seen, Lucretius describes a violent storm, and shows that the invisible particles of air act in the same way as the visible particles of water. We perceive, moreover, the different smells of things, yet never see them coming to our nostrils. Again, clothes hung up on a shore which waves break upon, become moist, and then get dry if spread out in the sun, though no eye can see either the approach or the escape of the water particles. A ring, worn long on the finger, becomes thinner; a water-drop hollows out a stone; the plowshare is rubbed away in the field; the street-pavement is worn by the feet; but the particles that disappear at any moment we cannot see. Nature acts through invisible particles. That Lucretius had a strong scientific imagination the foregoing references prove. A fine illustration of his power in this respect is his explanation of the apparent rest of bodies whose atoms are in motion. He employs the image of a flock of sheep with skipping lambs, which, seen from a distance, presents simply a white patch upon the green hill, the jumping of the individual lambs being quite invisible.

His vaguely grand conception of the atoms falling eternally through space, suggested the nebular hypothesis to Kant, its first propounder. Far beyond the limits of our

[1] Monro's translation. In his criticism of this work ("Contemporary Review," 1867) Dr. Hayman does not appear to be aware of the really sound and subtile observations on which the reasoning of Lucretius, though erroneous, sometimes rests.

visible world are to be found atoms innumerable, which have never been united to form bodies, or which, if once united, have been again dispersed—falling silently through immeasurable intervals of time and space. As everywhere throughout the All the same conditions are repeated, so must the phenomena be repeated also. Above us, below us, beside us, therefore, are worlds without end; and this, when considered, must dissipate every thought of a deflection of the universe by the gods. The worlds come and go, attracting new atoms out of limitless space, or dispersing their own particles. The reputed death of Lucretius, which forms the basis of Mr. Tennyson's noble poem, is in strict accordance with his philosophy, which was severe and pure.

§ 2

Still earlier than these three philosophers, and during the centuries between the first of them and the last, the human intellect was active in other fields than theirs. Pythagoras had founded a school of mathematics, and made his experiments on the harmonic intervals. The Sophists had run through their career. At Athens had appeared Socrates, Plato, and Aristotle, who ruined the Sophists, and whose yoke remains to some extent unbroken to the present hour. Within this period also the School of Alexandria was founded, Euclid wrote his "Elements" and made some advance in optics. Archimedes had propounded the theory of the lever, and the principles of hydrostatics. Astronomy was immensely enriched by the discoveries of Hipparchus, who was followed by the historically more celebrated Ptolemy. Anatomy had been made the basis of scientific medicine; and it is said

by Draper[1] that vivisection had begun. In fact, the science of ancient Greece had already cleared the world of the fantastic images of divinities operating capriciously through natural phenomena. It had shaken itself free from that fruitless scrutiny "by the internal light of the mind alone," which had vainly sought to transcend experience, and to reach a knowledge of ultimate causes. Instead of accidental observation, it had introduced observation with a purpose; instruments were employed to aid the senses; and scientific method was rendered in a great measure complete by the union of Induction and Experiment.

What, then, stopped its victorious advance? Why was the scientific intellect compelled, like an exhausted soil, to lie fallow for nearly two millenniums, before it could regather the elements necessary to its fertility and strength? Bacon has already let us know one cause; Whewell ascribes this stationary period to four causes—obscurity of thought, servility, intolerance of disposition, enthusiasm of temper; and he gives striking examples of each.[2] But these characteristics must have had their antecedents in the circumstances of the time. Rome, and the other cities of the Empire, had fallen into moral putrefaction. Christianity had appeared, offering the Gospel to the poor, and by moderation, if not asceticism of life, practically protesting against the profligacy of the age. The sufferings of the early Christians, and the extraordinary exaltation of mind which enabled them to triumph over the diabolical tortures to which they were subjected,[3] must have left

[1] "History of the Intellectual Development of Europe," p. 295.

[2] "History of the Inductive Sciences," vol. i.

[3] Described with terrible vividness in Renan's "Antichrist."

traces not easily effaced. They scorned the earth, in view of that "building of God, that house not made with hands, eternal in the heavens." The Scriptures which ministered to their spiritual needs were also the measure of their Science. When, for example, the celebrated question of the Antipodes came to be discussed, the Bible was with many the ultimate court of appeal. Augustine, who flourished A.D. 400, would not deny the rotundity of the earth; but he would deny the possible existence of inhabitants at the other side, "because no such race is recorded in Scripture among the descendants of Adam." Archbishop Boniface was shocked at the assumption of a "world of human beings out of the reach of the means of salvation." Thus reined in, Science was not likely to make much progress. Later on, the political and theological strife between the Church and civil governments, so powerfully depicted by Draper, must have done much to stifle investigation.

Whewell makes many wise and brave remarks regarding the spirit of the Middle Ages. It was a menial spirit. The seekers after natural knowledge had forsaken the fountain of living waters, the direct appeal to Nature by observation and experiment, and given themselves up to the remanipulation of the notions of their predecessors. It was a time when thought had become abject, and when the acceptance of mere authority led, as it always does in science, to intellectual death. Natural events, instead of being traced to physical, were referred to moral, causes; while an exercise of the fantasy, almost as degrading as the spiritualism of the present day, took the place of scientific speculation. Then came the mysticism of the Middle Ages, Magic, Alchemy, the Neoplatonic philosophy, with its visionary though sublime abstractions, which caused

men to look with shame upon their own bodies, as hinderances to the absorption of the creature in the blessedness of the Creator. Finally came the scholastic philosophy, a fusion, according to Lange, of the least mature notions of Aristotle with the Christianity of the West. Intellectual immobility was the result. As a traveller without a compass in a fog may wander long, imagining he is making way, and find himself after hours of toil at his starting-point, so the schoolmen, having "tied and untied the same knots, and formed and dissipated the same clouds,"[1] found themselves at the end of centuries in their old position.

With regard to the influence wielded by Aristotle in the Middle Ages, and which, to a less extent, he still wields, I would ask permission to make one remark. When the human mind has achieved greatness and given evidence of extraordinary power in one domain, there is a tendency to credit it with similar power in all other domains. Thus theologians have found comfort and assurance in the thought that Newton dealt with the question of revelation—forgetful of the fact that the very devotion of his powers, through all the best years of his life, to a totally different class of ideas, not to speak of any natural disqualification, tended to render him less, instead of more, competent to deal with theological and historic questions. Goethe, starting from his established greatness as a poet, and indeed from his positive discoveries in Natural History, produced a profound impression among the painters of Germany, when he published his "Farbenlehre," in which he endeavored to overthrow Newton's theory of

[1] Whewell.

colors. This theory he deemed so obviously absurd that he considered its author a charlatan, and attacked him with a corresponding vehemence of language. In the domain of Natural History, Goethe had made really considerable discoveries; and we have high authority for assuming that, had he devoted himself wholly to that side of science, he might have reached an eminence comparable with that which he attained as a poet. In sharpness of observation, in the detection of analogies apparently remote, in the classification and organization of facts according to the analogies discerned, Goethe possessed extraordinary powers. These elements of scientific inquiry fall in with the disciplines of the poet. But, on the other hand, a mind thus richly endowed in the direction of natural history, may be almost shorn of endowment as regards the physical and mechanical sciences. Goethe was in this condition. He could not formulate distinct mechanical conceptions; he could not see the force of mechanical reasoning; and, in regions where such reasoning reigns supreme, he became a mere *ignis fatuus* to those who followed him.

I have sometimes permitted myself to compare Aristotle with Goethe—to credit the Stagirite with an almost superhuman power of amassing and systematizing facts, but to consider him fatally defective on that side of the mind, in respect to which incompleteness has been just ascribed to Goethe. Whewell refers the errors of Aristotle not to a neglect of facts, but to "a neglect of the idea appropriate to the facts: the idea of Mechanical cause, which is Force, and the substitution of vague or inapplicable notions, involving only relations of space or emotions of wonder." This is doubtless true; but the

word "neglect" implies mere intellectual misdirection, whereas in Aristotle, as in Goethe, it was not, I believe, misdirection, but sheer natural incapacity which lay at the root of his mistakes. As a physicist, Aristotle displayed what we should consider some of the worst of attributes in a modern physical investigator indistinctness of ideas, confusion of mind, and a confident use of language which led to the delusive notion that he had really mastered his subject, while he had, as yet, failed to grasp even the elements of it. He put words in the place of things, subject in the place of object. He preached Induction without practicing it, inverting the true order of inquiry, by passing from the general to the particular, instead of from the particular to the general. He made of the universe a closed sphere, in the centre of which he fixed the earth, proving from general principles, to his own satisfaction and to that of the world for near 2,000 years, that no other universe was possible. His notions of motion were entirely unphysical. It was natural or unnatural, better or worse, calm or violent—no real mechanical conception regarding it lying at the bottom of his mind. He affirmed that a vacuum could not exist, and proved that if it did motion in it would be impossible. He determined *à priori* how many species of animals must exist, and showed on general principles why animals must have such and such parts. When an eminent contemporary philosopher, who is far removed from errors of this kind, remembers these abuses of the *à priori* method, he will be able to make allowance for the jealousy of physicists as to the acceptance of so-called *à priori* truths. Aristotle's errors of detail, as shown by Eucken and Lange, were grave and

numerous. He affirmed that only in man we had the beating of the heart, that the left side of the body was colder than the right, that men have more teeth than women, and that there is an empty space at the back of every man's head.

There is one essential quality in physical conceptions which was entirely wanting in those of Aristotle and his followers—a capability of being placed as coherent pictures before the mind. The Germans express the act of picturing by the word *vorstellen*, and the picture they call a *Vorstellung*. We have no word in English which comes nearer to our requirements than *Imagination;* and, taken with its proper limitations, the word answers very well. But it is tainted by its associations, and therefore objectionable to some minds. Compare, with reference to this capacity of mental presentation, the case of the Aristotelian, who refers the ascent of water in a pump to Nature's abhorrence of a vacuum, with that of Pascal when he proposed to solve the question of atmospheric pressure by the ascent of the Puy de Dôme. In the one case the terms of the explanation refuse to fall into place as a physical image; in the other the image is distinct, the descent and rise of the barometer being clearly figured beforehand as the balancing of two varying and opposing pressures.

§ 3

During the drought of the Middle Ages in Christendom, the Arabian intellect, as forcibly shown by Draper, was active. With the intrusion of the Moors into Spain, order, learning, and refinement took the place of their opposites. When smitten with disease, the Christian peasant resorted to a shrine, the Moorish one to an instructed

physician. The Arabs encouraged translations from the Greek philosophers, but not from the Greek poets. They turned in disgust "from the lewdness of our classical mythology, and denounced as an unpardonable blasphemy all connection between the impure Olympian Jove and the Most High God." Draper traces still further than Whewell the Arab elements in our scientific terms. He gives examples of what Arabian men of science accomplished, dwelling particularly on Alhazen, who was the first to correct the Platonic notion that rays of light are emitted by the eye. Alhazen discovered atmospheric refraction, and showed that we see the sun and the moon after they have set. He explained the enlargement of the sun and moon, and the shortening of the vertical diameters of both these bodies when near the horizon. He was aware that the atmosphere decreases in density with increase of elevation, and actually fixed its height at 58½ miles. In the "Book of the Balance of Wisdom," he sets forth the connection between the weight of the atmosphere and its increasing density. He shows that a body will weigh differently in a rare and dense atmosphere, and he considers the force with which plunged bodies rise through heavier media. He understood the doctrine of the centre of gravity, and applied it to the investigation of balances and steelyards. He recognized gravity as a force, though he fell into the error of assuming it to diminish simply as the distance, and of making it purely terrestrial. He knew the relation between the velocities, spaces, and times of falling bodies, and had distinct ideas of capillary attraction. He improved the hydrometer. The determinations of the densities of bodies, as given by Alhazen, approach very closely to our own. "I join," says Draper, "in the

ous prayer of Alhazen, that in the day of judgment the ll-Merciful will take pity on the soul of Abur-Raihân, ecause he was the first of the race of men to construct table of specific gravities." If all this be historic truth nd I have entire confidence in Dr. Draper), well may "deplore the systematic manner in which the literature Europe has contrived to put out of sight our scientific oligations to the Mohammedans."[1]

The strain upon the mind during the stationary period ward ultra-terrestrial things, to the neglect of problems ose at hand, was sure to provoke reaction. But the re- tion was gradual; for the ground was dangerous, and power was at hand competent to crush the critic who ent too far. To elude this power, and still allow oppor- nity for the expression of opinion, the doctrine of "two- ld truth" was invented, according to which an opinion ight be held "theologically," and the opposite opinion philosophically."[2] Thus, in the thirteenth century, the cation of the world in six days, and the unchangeable- ess of the individual soul, which had been so distinctly firmed by St. Thomas Aquinas, were both denied phil- sophically, but admitted to be true as articles of the atholic faith. When Protagoras uttered the maxim which rought upon him so much vituperation, that "opposite ssertions are equally true," he simply meant to affirm en's differences to be so great, that what was subject- vely true to the one might be subjectively untrue to the her. The great Sophist never meant to play fast and ose with the truth by saying that one of two opposite

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[1] "Intellectual Development of Europe," p. 359.

[2] "Lange, 2d edit., pp. 181, 182.

assertions, made by the same individual, could possibly escape being a lie. It was not "sophistry," but the dread of theologic vengeance, that generated this double dealing with conviction; and it is astonishing to notice what lengths were allowed to men who were adroit in the use of artifices of this kind.

Toward the close of the stationary period a word-weariness, if I may so express it, took more and more possession of men's minds. Christendom had become sick of the School Philosophy and its verbal wastes, which led to no issue, but left the intellect in everlasting haze. Here and there was heard the voice of one impatiently crying in the wilderness, "Not unto Aristotle, not unto subtle hypothesis, not unto Church, Bible, or blind tradition, must we turn for a knowledge of the universe, but to the direct investigation of Nature by observation and experiment." In 1543 the epoch-marking work of Copernicus on the paths of the heavenly bodies appeared. The total crash of Aristotle's closed universe, with the earth at its centre, followed as a consequence, and "The earth moves!" became a kind of watchword among intellectual freemen. Copernicus was Canon of the church of Frauenburg in the diocese of Ermeland. For three-and-thirty years he had withdrawn himself from the world, and devoted himself to the consolidation of his great scheme of the solar system. He made its blocks eternal; and even to those who feared it, and desired its overthrow, it was so obviously strong that they refrained for a time from meddling with it. In the last year of the life of Copernicus his book appeared: it is said that the old man received a copy of it a few days before his death, and then departed in peace.

The Italian philosopher, Giordano Bruno, was one of the earliest converts to the new astronomy. Taking Lucretius as his exemplar, he revived the notion of the infinity of worlds; and, combining with it the doctrine of Copernicus, reached the sublime generalization that the fixed stars are suns, scattered numberless through space, and accompanied by satellites, which bear the same relation to them that our earth does to our sun, or our moon to our earth. This was an expansion of transcendent import; but Bruno came closer than this to our present line of thought. Struck with the problem of the generation and maintenance of organisms, and duly pondering it, he came to the conclusion that Nature, in her productions, does not imitate the technic of man. Her process is one of unravelling and unfolding. The infinity of forms under which matter appears was not imposed upon it by an external artificer; by its own intrinsic force and virtue it brings these forms forth. Matter is not the mere naked, empty *capacity* which philosophers have pictured her to be, but the universal mother, who brings forth all things as the fruit of her own womb.

This outspoken man was originally a Dominican monk. He was accused of heresy and had to fly, seeking refuge in Geneva, Paris, England and Germany. In 1592 he fell into the hands of the Inquisition at Venice. He was imprisoned for many years, tried, degraded, excommunicated, and handed over to the Civil power, with the request that he should be treated gently, and "without the shedding of blood." This meant that he was to be burned; and burned accordingly he was, on February 16, 1600. To escape a similar fate Galileo, thirty-three years afterward, abjured upon his knees, with his hands upon the holy

Gospels, the heliocentric doctrine, which he knew to be true. After Galileo came Kepler, who from his German home defied the ultramontane power. He traced out from pre-existing observations the laws of planetary motion. Materials were thus prepared for Newton, who bound those empirical laws together by the principle of gravitation.

§ 4

In the seventeenth century Bacon and Descartes, the restorers of philosophy, appeared in succession. Differently educated and endowed, their philosophic tendencies were different. Bacon held fast to Induction, believing firmly in the existence of an external world, and making collected experiences the basis of all knowledge. The mathematical studies of Descartes gave him a bias toward Deduction; and his fundamental principle was much the same as that of Protagoras, who made the individual man the measure of all things. "I think, therefore I am," said Descartes. Only his own identity was sure to him; and the full development of this system would have led to an idealism, in which the outer world would have been resolved into a mere phenomenon of consciousness. Gassendi, one of Descartes's contemporaries, of whom we shall hear more presently, quickly pointed out that the fact of personal existence would be proved as well by reference to any other act, as to the act of thinking. I eat, therefore I am, or I love, therefore I am, would be quite as conclusive. Lichtenberg, indeed, showed that the very thing to be proved was inevitably postulated in the first two words, "I think"; and it is plain that no inference from the postulate could, by any possibility, be stronger than the postulate itself.

But Descartes deviated strangely from the idealism im-
lied in his fundamental principle. He was the first to
educe, in a manner eminently capable of bearing the test
f mental presentation, vital phenomena to purely mechan-
cal principles. Through fear or love, Descartes was a
ood churchman; he accordingly rejected the notion of an
tom, because it was absurd to suppose that God, if He so
leased, could not divide an atom; he puts in the place
f the atoms small round particles, and light splinters, out
f which he builds the organism. He sketches with mar-
ellous physical insight a machine, with water for its mo-
ve power, which shall illustrate vital actions. He has
nade clear to his mind that such a machine would be
ompetent to carry on the processes of digestion, nutri-
on, growth, respiration, and the beating of the heart. It
ould be competent to accept impressions from the ex-
ernal sense, to store them up in imagination and mem-
ry, to go through the internal movements of the appe-
tes and passions, and the external movements of the
mbs. He deduces these functions of his machine from
e mere arrangements of its organs, as the movement of
clock, or other automaton, is deduced from its weights
nd wheels. "As far as these functions are concerned,"
e says, "it is not necessary to conceive any other vegeta-
ve or sensitive soul, nor any other principle of motion
of life, than the blood and the spirits agitated by the
re which burns continually in the heart, and which is
nowise different from the fires existing in inanimate
odies." Had Descartes been acquainted with the steam-
ngine, he would have taken it, instead of a fall of water,
his motive power. He would have shown the perfect
nalogy which exists between the oxidation of the food in

the body, and that of the coal in the furnace. He would assuredly have anticipated Mayer in calling the blood which the heart diffuses "the oil of the lamp of life," deducing all animal motions from the combustion of this oil, as the motions of a steam-engine are deduced from the combustion of its coal. As the matter stands, however, and considering the circumstances of the time, the boldness, clearness, and precision, with which Descartes grasped the problem of vital dynamics constitute a marvellous illustration of intellectual power.[1]

During the Middle Ages the doctrine of atoms had to all appearance vanished from discussion. It probably held its ground among sober-minded and thoughtful men, though neither the church nor the world was prepared to hear of it with tolerance. Once, in the year 1348, it received distinct expression. But retractation by compulsion immediately followed; and, thus discouraged, it slumbered till the seventeenth century, when it was revived by a contemporary and friend of Hobbes of Malmesbury, the orthodox Catholic provost of Digne, Gassendi. But, before stating his relation to the Epicurean doctrine, it will be well to say a few words on the effect, as regards science, of the general introduction of monotheism among European nations.

"Were men," says Hume, "led into the apprehension of invisible intelligent power by contemplation of the works of Nature, they could never possibly entertain any conception but of one single Being, who bestowed existence and order on this vast machine, and adjusted all its

[1] See Huxley's admirable "Essay on Descartes,"—"Lay Sermons," pp. 364, 365.

parts to one regular system." Referring to the condition of the heathen, who sees a god behind every natural event, thus peopling the world with thousands of beings whose caprices are incalculable, Lange shows the impossibility of any compromise between such notions and those of science, which proceeds on the assumption of never-changing law and causality. "But," he continues, with characteristic penetration, "when the great thought of one God, acting as a unit upon the universe, has been seized, the connection of things in accordance with the law of cause and effect is not only thinkable, but it is a necessary consequence of the assumption. For when I see ten thousand wheels in motion, and know, or believe, that they are all driven by one motive power, then I know that I have before me a mechanism, the action of every part of which is determined by the plan of the whole. So much being assumed, it follows that I may investigate the structure of that machine, and the various motions of its parts. For the time being, therefore, this conception renders scientific action free." In other words, were a capricious God at the circumference of every wheel and at the end of every lever, the action of the machine would be incalculable by the methods of science. But the actions of all its parts being rigidly determined by their connections and relations, and these being brought into play by a single motive power, then, though this last prime mover may elude me, I am still able to comprehend the machinery which it sets in motion. We have here a conception of the relation of Nature to its Author, which seems perfectly acceptable to some minds, but perfectly intolerable to others. Newton and Boyle lived and worked happily under the influence of this conception; Goethe rejected it

with vehemence, and the same repugnance to accepting it is manifest in Carlyle.[1]

The analytic and synthetic tendencies of the human mind are traceable throughout history, great writers ranging themselves sometimes on the one side, sometimes on the other. Men of warm feelings, and minds open to the elevating impressions produced by nature as a whole, whose satisfaction, therefore, is rather ethical than logical, lean to the synthetic side; while the analytic harmonizes best with the more precise and more mechanical bias which seeks the satisfaction of the understanding. Some form of pantheism was usually adopted by the one, while a detached Creator, working more or less after the manner of men, was often assumed by the other. Gassendi, as sketched by Lange, is hardly to be ranked with either. Having formally acknowledged God as the great first cause, he immediately dropped the idea, applied the known laws of mechanics to the atoms, and deduced from them all vital phenomena. He defended Epicurus, and dwelt upon his purity, both of doctrine and of life. True he was a heathen, but so was Aristotle. Epicurus assailed superstition and religion, and rightly, because he did not know the true religion. He thought that the gods neither rewarded nor punished, and he adored them purely in consequence of their completeness: here we see, says Gassendi, the reverence of the child, instead of the fear of

[1] Boyle's model of the universe was the Strasburg clock with an outside Artificer. Goethe, on the other hand, sang—

> "Ihm ziemt's die Welt im Innern zu bewegen,
> Natur in sich, sich in Natur zu hegen."

See also Carlyle, "Past and Present," chap. v.

the slave. The errors of Epicurus shall be corrected, and the body of his truth retained. Gassendi then proceeds, as any heathen might have done, to build up the world, and all that therein is, of atoms and molecules. God, who created earth and water, plants and animals, produced in the first place a definite number of atoms, which constituted the seed of all things. Then began that series of combinations and decompositions which now goes on, and which will continue in future. The principle of every change resides in matter. In artificial productions the moving principle is different from the material worked upon; but in nature the agent works within, being the most active and mobile part of the material itself. Thus this bold ecclesiastic, without incurring the censure of the church or the world, contrives to outstrip Mr. Darwin. The same cast of mind which caused him to detach the Creator from his universe, led him also to detach the soul from the body, though to the body he ascribes an influence so large as to render the soul almost unnecessary. The aberrations of reason were, in his view, an affair of the material brain. Mental disease is brain-disease; but then the immortal reason sits apart, and cannot be touched by the disease. The errors of madness are those of the instrument, not of the performer.

It may be more than a mere result of education, connecting itself, probably, with the deeper mental structure of the two men, that the idea of Gassendi, above enunciated, is substantially the same as that expressed by Professor Clerk Maxwell, at the close of the very able lecture delivered by him at Bradford in 1873. According to both philosophers, the atoms, if I understand aright, are *prepared materials*, which, formed once for all by the

Eternal, produce by their subsequent interaction all the phenomena of the material world. There seems to be this difference, however, between Gassendi and Maxwell. The one *postulates*, the other *infers* his first cause. In his "manufactured articles," as he calls the atoms, Professor Maxwell finds the basis of an induction, which enables him to scale philosophic heights considered inaccessible by Kant, and to take the logical step from the atoms to their Maker.

Accepting here the leadership of Kant, I doubt the legitimacy of Maxwell's logic; but it is impossible not to feel the ethic glow with which his lecture concludes. There is, moreover, a very noble strain of eloquence in his description of the steadfastness of the atoms: "Natural causes, as we know, are at work, which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred and may yet occur in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation stones of the material universe—remain unbroken and unworn."

The atomic doctrine, in whole or in part, was entertained by Bacon, Descartes, Hobbes, Locke, Newton, Boyle, and their successors, until the chemical law of multiple proportions enabled Dalton to confer upon it an entirely new significance. In our day there are secessions from the theory, but it still stands firm. Loschmidt, Stoney, and Sir William Thomson have sought to determine the sizes of the atoms, or rather to fix the limits between which their sizes lie; while the discourses of Wil-

liamson and Maxwell delivered in Bradford in 1873 illustrate the present hold of the doctrine upon the foremost scientific minds. In fact, it may be doubted whether, wanting this fundamental conception, a theory of the material universe is capable of scientific statement.

§ 5

Ninety years subsequent to Gassendi the doctrine of bodily instruments, as it may be called, assumed immense importance in the hands of Bishop Butler, who, in his famous "Analogy of Religion," developed, from his own point of view, and with consummate sagacity, a similar idea. The Bishop still influences many superior minds; and it will repay us to dwell for a moment on his views. He draws the sharpest distinction between our real selves and our bodily instruments. He does not, as far as I remember, use the word soul, possibly because the term was so hackneyed in his day, as it had been for many generations previously. But he speaks of "living powers," "perceiving or percipient powers," "moving agents," "ourselves," in the same sense as we should employ the term soul. He dwells upon the fact that limbs may be removed and mortal diseases assail the body, the mind, almost up to the moment of death, remaining clear. He refers to sleep and to swoon, where the "living powers" are suspended but not destroyed. He considers it quite as easy to conceive of existence out of our bodies as in them; that we may animate a succession of bodies, the dissolution of all of them having no more tendency to dissolve our real selves, or "deprive us of living faculties—the faculties of perception and action—than the dissolution of any foreign matter which we are capable of receiving

impressions from, or making use of for the common occasions of life." This is the key of the Bishop's position: "our organized bodies are no more a part of ourselves than any other matter around us." In proof of this he calls attention to the use of glasses, which "prepare objects" for the "percipient power" exactly as the eye does. The eye itself is no more percipient than the glass; is quite as much the instrument of the true self, and also as foreign to the true self, as the glass is. "And if we see with our eyes only in the same manner as we do with glasses, the like may justly be concluded from analogy of all our senses."

Lucretius, as you are aware, reached a precisely opposite conclusion: and it certainly would be interesting, if not profitable, to us all, to hear what he would or could urge in opposition to the reasoning of the Bishop. As a brief discussion of the point will enable us to see the bearings of an important question, I will here permit a disciple of Lucretius to try the strength of the Bishop's position, and then allow the Bishop to retaliate, with the view of rolling back, if he can, the difficulty upon Lucretius.

The argument might proceed in this fashion:

"Subjected to the test of mental presentation (*Vorstellung*), your views, most honored prelate, would offer to many minds a great, if not an insuperable, difficulty. You speak of 'living powers,' 'percipient or perceiving powers,' and 'ourselves'; but can you form a mental picture of any of these, apart from the organism through which it is supposed to act? Test yourself honestly, and see whether you possess any faculty that would enable you to form such a conception. The true self has a local habitation in each of us; thus localized, must it not possess a form? If so,

stroke have been much longer in the same state; and indeed in cases of ordinary concussion of the brain, days may elapse during which no experience is registered in consciousness. Where is the man himself during the period of insensibility? You may say that I beg the question when I assume the man to have been unconscious, that he was really conscious all the time, and has simply forgotten what had occurred to him. In reply to this, I can only say that no one need shrink from the worst tortures that superstition ever invented, if only so felt and so remembered. I do not think your theory of instruments goes at all to the bottom of the matter. A telegraph operator has his instruments, by means of which he converses with the world; our bodies possess a nervous system, which plays a similar part between the perceiving power and external things. Cut the wires of the operator, break his battery, demagnetize his needle; by this means you certainly sever his connection with the world: but, inasmuch as these are real instruments, their destruction does not touch the man who uses them. The operator survives, *and he knows that he survives.* What is there, I would ask, in the human system that answers to this conscious survival of the operator when the battery of the brain is so disturbed as to produce insensibility, or when it is destroyed altogether?

"Another consideration, which you may regard as slight, presses upon me with some force. The brain may change from health to disease, and through such a change the most exemplary man may be converted into a debauchee or a murderer. My very noble and approved good master had, as you know, threatenings of lewdness introduced into his brain by his jealous wife's philter; and

sooner than permit himself to run even the risk of yielding to these base promptings he slew himself. How could the hand of Lucretius have been thus turned against himself if the real Lucretius remained as before? Can the brain, or can it not, act in this distempered way without the intervention of the immortal reason? If it can, then it is a prime mover which requires only healthy regulation to render it reasonably self-acting, and there is no apparent need of your immortal reason at all. If it cannot, then the immortal reason, by its mischievous activity in operating upon a broken instrument, must have the credit of committing every imaginable extravagance and crime. I think, if you will allow me to say so, that the gravest consequences are likely to flow from your estimate of the body. To regard the brain as you would a staff or an eyeglass—to shut your eyes to all its mystery, to the perfect correlation of its condition and our consciousness, to the fact that a slight excess or defect of blood in it produces the very swoon to which you refer, and that in relation to it our meat, and drink, and air, and exercise, have a perfectly transcendental value and significance—to forget all this does, I think, open a way to innumerable errors in our habits of life, and may possibly, in some cases, initiate and foster that very disease, and consequent mental ruin, which a wiser appreciation of this mysterious organ would have avoided."

I can imagine the Bishop thoughtful after hearing this argument. He was not the man to allow anger to mingle with the consideration of a point of this kind. After due reflection, and having strengthened himself by that honest contemplation of the facts which was habitual with him, and which includes the desire to give even adverse

reasonings their due weight, I can suppose the Bishop to proceed thus: "You will remember that in the 'Analogy of Religion,' of which you have so kindly spoken, I did not profess to prove anything absolutely, and that I over and over again acknowledged and insisted on the smallness of our knowledge, or rather the depth of our ignorance, as regards the whole system of the universe. My object was to show my deistical friends, who set forth so eloquently the beauty and beneficence of Nature and the Ruler thereof, while they had nothing but scorn for the so-called absurdities of the Christian scheme, that they were in no better condition than we were, and that, for every difficulty found upon our side, quite as great a difficulty was to be found upon theirs. I will now, with your permission, adopt a similar line of argument. You are a Lucretian, and from the combination and separation of insensate atoms deduce all terrestrial things, including organic forms and their phenomena. Let me tell you in the first instance how far I am prepared to go with you. I admit that you can build crystalline forms out of this play of molecular force; that the diamond, amethyst, and snow-star are truly wonderful structures which are thus produced. I will go further and acknowledge that even a tree or flower might in this way be organized. Nay, if you can show me an animal without sensation, I will concede to you that it also might be put together by the suitable play of molecular force.

"Thus far our way is clear, but now comes my difficulty. Your atoms are individually without sensation, much more are they without intelligence. May I ask you, then, to try your hand upon this problem. Take your dead hydrogen atoms, your dead oxygen atoms,

your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless; observe them running together and forming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to rise? Are you likely to extract Homer out of the rattling of dice, or the Differential Calculus out of the clash of billiard-balls? I am not all bereft of this *Vorstellungs-Kraft* of which you speak, nor am I, like so many of my brethren, a mere vacuum as regards scientific knowledge. I can follow a particle of musk until it reaches the olfactory nerve; I can follow the waves of sound until their tremors reach the water of the labyrinth, and set the otoliths and Corti's fibres in motion; I can also visualize the waves of ether as they cross the eye and hit the retina. Nay more, I am able to pursue to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processes. What baffles and bewilders me is the notion that from those physical tremors things so utterly incongruous with them, as sensation, thought, and emotion, can be derived. You may say, or think, that this issue of consciousness from the clash of atoms is not more incongruous than the flash of light from the union of oxygen and hydrogen. But I beg to say that it is. For such incongruity as the flash possesses is that which I now force upon your attention. The "flash" is an affair of consciousness, the objective

counterpart of which is a vibration. It is a flash only by your interpretation. *You* are the cause of the apparent incongruity; and *you* are the thing that puzzles me. I need not remind you that the great Leibnitz felt the difficulty which I feel; and that, to get rid of this monstrous deduction of life from death, he displaced your atoms by his monads, which were more or less perfect mirrors of the universe, and out of the summation and integration of which he supposed all the phenomena of life—sentient, intellectual, and emotional—to arise.

"Your difficulty, then, as I see you are ready to admit, is quite as great as mine. You cannot satisfy the human understanding in its demand for logical continuity between molecular processes and the phenomena of consciousness. This is a rock on which Materialism must inevitably split whenever it pretends to be a complete philosophy of life. What is the moral, my Lucretian? You and I are not likely to indulge in ill-temper in the discussion of these great topics, where we see so much room for honest differences of opinion. But there are people of less wit or more bigotry (I say it with humility), on both sides, who are ever ready to mingle anger and vituperation with such discussions. There are, for example, writers of note and influence at the present day who are not ashamed publicly to assume the 'deep personal sin' of a great logician to be the cause of his unbelief in a theologic dogma.[1] And

[1] This is the aspect under which the late Editor of the "Dublin Review" presented to his readers the memory of John Stuart Mill. I can only say that I would as soon take my chance in the other world, in the company of the "unbeliever," as in that of his Jesuit detractor. In Dr. Ward we have an example of a wholesome and vigorous nature, soured and perverted by a poisonous creed.

there are others who hold that we, who cherish our noble Bible, wrought as it has been into the constitution of our forefathers, and by inheritance into us, must necessarily be hypocritical and insincere. Let us disavow and discountenance such people, cherishing the unswerving faith that what is good and true in both our arguments will be preserved for the benefit of humanity, while all that is bad or false will disappear."

I hold the Bishop's reasoning to be unanswerable, and his liberality to be worthy of imitation.

It is worth remarking that in one respect the Bishop was a product of his age. Long previous to his day the nature of the soul had been so favorite and general a topic of discussion that, when the students of the Italian Universities wished to know the leanings of a new Professor, they at once requested him to lecture upon the soul. About the time of Bishop Butler the question was not only agitated, but extended. It was seen by the clear-witted men who entered this arena that many of their best arguments applied equally to brutes and men. The Bishop's arguments were of this character. He saw it, admitted it, took the consequence, and boldly embraced the whole animal world in his scheme of immortality.

§ 6

Bishop Butler accepted with unwavering trust the chronology of the Old Testament, describing it as "confirmed by the natural and civil history of the world, collected from common historians, from the state of the earth, and from the late inventions of arts and sciences." These words mark progress; and they must seem somewhat hoary to the Bishop's successors of to-day. It is

hardly necessary to inform you that since his time the domain of the naturalist has been immensely extended—the whole science of geology, with its astounding revelations regarding the life of the ancient earth, having been created. The rigidity of old conceptions has been relaxed, the public mind being rendered gradually tolerant of the idea that not for six thousand, nor for sixty thousand, nor for six thousand thousand, but for eons embracing untold millions of years, this earth has been the theatre of life and death. The riddle of the rocks has been read by the geologist and paleontologist, from sub-cambrian depths to the deposits thickening over the sea-bottoms of to-day. And upon the leaves of that stone book are, as you know, stamped the characters, plainer and surer than those formed by the ink of history, which carry the mind back into abysses of past time, compared with which the periods which satisfied Bishop Butler cease to have a visual angle.

The lode of discovery once struck, those petrified forms in which life was at one time active, increased to multitudes and demanded classification. They were grouped in genera, species, and varieties, according to the degree of similarity subsisting between them. Thus confusion was avoided, each object being found in the pigeon-hole appropriated to it and to its fellows of similar morphological or physiological character. The general fact soon became evident that none but the simplest forms of life lie lowest down; that, as we climb higher among the superimposed strata, more perfect forms appear. The change, however, from form to form was not continuous, but by steps—some small, some great. "A section," says Mr. Huxley, "a hundred feet thick will exhibit at different

heights a dozen species of Ammonite, none of which passes beyond the particular zone of limestone, or clay, into the zone below it, or into that above it." In the presence of such facts it was not possible to avoid the question: Have these forms, showing, though in broken stages, and with many irregularities, this unmistakable general advance, been subjected to no continuous law of growth or variation? Had our education been purely scientific, or had it been sufficiently detached from influences which, however ennobling in another domain, have always proved hinderances and delusions when introduced as factors into the domain of physics, the scientific mind never could have swerved from the search for a law of growth, or allowed itself to accept the anthropomorphism which regarded each successive stratum as a kind of mechanic's bench for the manufacture of new species out of all relation to the old.

Biased, however, by their previous education, the great majority of naturalists invoked a special creative act to account for the appearance of each new group of organisms. Doubtless numbers of them were clear-headed enough to see that this was no explanation at all—that, in point of fact, it was an attempt, by the introduction of a greater difficulty, to account for a less. But, having nothing to offer in the way of explanation, they for the most part held their peace. Still the thoughts of reflecting men naturally and necessarily simmered round the question. De Maillet, a contemporary of Newton, has been brought into notice by Professor Huxley as one who "had a notion of the modifiability of living forms." The late Sir Benjamin Brodie, a man of highly philosophic mind, often drew my attention to the fact that, as early as 1794, Charles Dar-

win's grandfather was the pioneer of Charles Darwin.[1] In 1801, and in subsequent years, the celebrated Lamarck, who, through the vigorous exposition of his views by the author of the "Vestiges of Creation," rendered the public mind perfectly familiar with the idea of evolution, endeavored to show the development of species out of changes of habit and external condition. In 1813 Dr. Wells, the founder of our present theory of Dew, read before the Royal Society a paper in which, to use the words of Mr. Darwin, "he distinctly recognizes the principle of natural selection; and this is the first recognition that has been indicated." The thoroughness and skill with which Wells pursued his work, and the obvious independence of his character, rendered him long ago a favorite with me; and it gave me the liveliest pleasure to alight upon this additional testimony to his penetration. Professor Grant, Mr. Patrick Matthew, Von Buch, the author of the "Vestiges," D'Halloy, and others, by the enunciation of opinions more or less clear and correct, showed that the question had been fermenting long prior to the year 1858, when Mr. Darwin and Mr. Wallace simultaneously, but independently, placed their closely concurrent views before the Linnean Society.[2]

These papers were followed in 1859 by the publication of the first edition of the "Origin of Species." All great things come slowly to the birth. Copernicus, as I informed you, pondered his great work for thirty-three years.

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[1] "Zoonomia," vol. i. pp. 500–510.

[2] In 1855 Mr. Herbert Spencer ("Principles of Psychology," 2d edit. vol. i. p. 465) expressed "the belief that life under all its forms has arisen by an unbroken evolution, and through the instrumentality of what are called natural causes." This was my belief also at that time.

Newton for nearly twenty years kept the idea of Gravitation before his mind; for twenty years also he dwelt upon his discovery of Fluxions, and doubtless would have continued to make it the object of his private thought, had he not found Leibnitz upon his track. Darwin for two-and-twenty years pondered the problem of the origin of species, and doubtless he would have continued to do so had he not found Wallace upon his track.[1] A concentrated, but full and powerful, epitome of his labors was the consequence. The book was by no means an easy one; and probably not one in every score of those who then attacked it, had read its pages through, or were competent to grasp their significance if they had. I do not say this merely to discredit them: for there were in those days some really eminent scientific men, entirely raised above the heat of popular prejudice, and willing to accept any conclusion that science had to offer, provided it was duly backed by fact and argument, who entirely mistook Mr. Darwin's views. In fact, the work needed an expounder, and it found one in Mr. Huxley. I know nothing more admirable in the way of scientific exposition than those early articles of his on the origin of species. He swept the curve of discussion through the really significant points of the subject, enriched his exposition with profound original remarks and reflections, often summing up in a single pithy sentence an argument which a less compact mind would have spread over pages. But there is one impression made by the book itself which no exposition of it, however luminous, can convey; and that

[1] The behavior of Mr. Wallace in relation to this subject has been dignified in the highest degree.

is the impression of the vast amount of labor, both of observation and of thought, implied in its production. Let us glance at its principles.

It is conceded on all hands that what are called "varieties" are continually produced. The rule is probably without exception. No chick, or child, is in all respects and particulars the counterpart of its brother and sister; and in such differences we have "variety" incipient. No naturalist could tell how far this variation could be carried; but the great mass of them held that never, by any amount of internal or external change, nor by the mixture of both, could the offspring of the same progenitor so far deviate from each other as to constitute different species. The function of the experimental philosopher is to combine the conditions of Nature and to produce her results; and this was the method of Darwin.[1] He made himself acquainted with what could, without any manner of doubt, be done in the way of producing variation. He associated himself with pigeon-fanciers—bought, begged, kept, and observed every breed that he could obtain. Though derived from a common stock, the diversities of these pigeons were such that "a score of them might be chosen which, if shown to an ornithologist, and he were told that they were wild birds, would certainly be ranked by him as well-defined species." The simple principle which guides the pigeon-fancier, as it does the cattle-breeder, is the selection of some variety that strikes his fancy, and the propagation of this variety by inheritance. With his eye

[1] The first step only toward experimental demonstration has been taken. Experiments now begun might, a couple of centuries hence, furnish data of incalculable value, which ought to be supplied to the science of the future.

directed to the particular appearance which he wishes
:aggerate, he selects it as it reappears in successive
ls, and thus adds increment to increment until an
ishing amount of divergence from the parent type is
ed. The breeder in this case does not produce the
nts of the variation. He simply observes them, and
lection adds them together until the required result
een obtained. "No man," says Mr. Darwin, "would
try to make a fantail till he saw a pigeon with a tail
oped in some slight degree in an unusual manner,
pouter until he saw a pigeon with a crop of unusual
' Thus nature gives the hint, man acts upon it, and
e law of inheritance exaggerates the deviation.

aving thus satisfied himself by indubitable facts that
rganization of an animal or of a plant (for precisely
ame treatment applies to plants) is to some extent
c, he passes from variation under domestication to
tion under nature. Hitherto we have dealt with the
g together of small changes by the conscious selec-
of man. Can Nature thus select? Mr. Darwin's
er is, "Assuredly she can." The number of living
s produced is far in excess of the number that can
pported; hence at some period or other of their lives
must be a struggle for existence. And what is the
ible result? If one organism were a perfect copy of
ther in regard to strength, skill, and agility, external
tions would decide. But this is not the case. Here
ave the fact of variety offering itself to nature, as in
ormer instance it offered itself to man; and those
ies which are least competent to cope with surround-
onditions will infallibly give way to those that are
competent. To use a familiar proverb, the weakest

goes to the wall. But the triumphant fraction again breeds to over-production, transmitting the qualities which secured its maintenance, but transmitting them in different degrees. The struggle for food again supervenes, and those to whom the favorable quality has been transmitted in excess, will triumph as before.

It is easy to see that we have here the addition of increments favorable to the individual, still more rigorously carried out than in the case of domestication; for not only are unfavorable specimens not selected by nature, but they are destroyed. This is what Mr. Darwin calls "Natural Selection," which acts by the preservation and accumulation of small inherited modifications, each profitable to the preserved being. With this idea he interpenetrates and leavens the vast store of facts that he and others have collected. We cannot, without shutting our eyes through fear or prejudice, fail to see that Darwin is here dealing, not with imaginary, but with true causes; nor can we fail to discern what vast modifications may be produced by natural selection in periods sufficiently long. Each individual increment may resemble what mathematicians call a "differential" (a quantity indefinitely small); but definite and great changes may obviously be produced by the integration of these infinitesimal quantities, through practically infinite time.

If Darwin, like Bruno, rejects the notion of creative power, acting after human fashion, it certainly is not because he is unacquainted with the numberless exquisite adaptations, on which this notion of a supernatural Artificer has been founded. His book is a repository of the most startling facts of this description. Take the marvellous observation which he cites from Dr. Krüger, where

bucket, with an aperture serving as a spout, is formed
an orchid. Bees visit the flower: in eager search of
terial for their combs, they push each other into the
cket, the drenched ones escaping from their involuntary
th by the spout. Here they rub their backs against the
cid stigma of the flower and obtain glue; then against
pollen-masses, which are thus stuck to the back of the
and carried away. "When the bee, so provided, flies
another flower, or to the same flower a second time, and
pushed by its comrades into the bucket, and then crawls
by the passage, the pollen-mass upon its back neces-
ily comes first into contact with the viscid stigma,"
ich takes up the pollen; and this is how that orchid
fertilized. Or take this other case of the *Catasetum.*
ees visit these flowers in order to gnaw the labellum;
doing this they inevitably touch a long, tapering, sensi-
e projection. This, when touched, transmits a sensa-
n or vibration to a certain membrane, which is instantly
tured, setting free a spring, by which the pollen-mass
shot forth like an arrow in the right direction, and ad-
res by its viscid extremity to the back of the bee." In
s way the fertilizing pollen is spread abroad.

It is the mind thus stored with the choicest materials
the teleologist that rejects teleology, seeking to refer
se wonders to natural causes. They illustrate, accord-
to him, the method of nature, not the "technic" of
manlike Artificer. The beauty of flowers is due to nat-
l selection. Those that distinguish themselves by viv
y contrasting colors from the surrounding green leaves
most readily seen, most frequently visited by insects,
st often fertilized, and hence most favored by natural
ection. Colored berries also readily attract the atten-

tion of birds and beasts, which feed upon them, spread their manured seeds abroad, thus giving trees and shrubs possessing such berries a greater chance in the struggle for existence.

With profound analytic and synthetic skill, Mr. Darwin investigates the cell-making instinct of the hive-bee. His method of dealing with it is representative. He falls back from the more perfectly to the less perfectly developed instinct—from the hive-bee to the humble bee, which uses its own cocoon as a comb, and to classes of bees of intermediate skill, endeavoring to show how the passage might be gradually made from the lowest to the highest. The saving of wax is the most important point in the economy of bees. Twelve to fifteen pounds of dry sugar are said to be needed for the secretion of a single pound of wax. The quantities of nectar necessary for the wax must therefore be vast; and every improvement of constructive instinct which results in the saving of wax is a direct profit to the insect's life. The time that would otherwise be devoted to the making of wax is devoted to the gathering and storing of honey for winter food. Mr. Darwin passes from the humble-bee with its rude cells, through the Melipona with its more artistic cells, to the hive-bee with its astonishing architecture. The bees place themselves at equal distances apart upon the wax, sweep and excavate equal spheres round the selected points. The spheres intersect, and the planes of intersection are built up with thin laminæ. Hexagonal cells are thus formed. This mode of treating such questions is, as I have said, representative. The expositor habitually retires from the more perfect and complex, to the less perfect and simple, and carries you with him through stages

perfecting—adds increment to increment of infinitesimal
ange, and in this way gradually breaks down your re-
tance to admit that the exquisite climax of the whole
ıld be a result of natural selection.

Mr. Darwin shirks no difficulty; and, saturated as the
oject was with his own thought, he must have known,
tter than his critics, the weakness as well as the strength
his theory. This of course would be of little avail were
object a temporary dialectic victory, instead of the es-
olishment of a truth which he means to be everlasting.
ıt he takes no pains to disguise the weakness he has
scerned; nay, he takes every pains to bring it into the
ongest light. His vast resources enable him to cope
th objections started by himself and others, so as to
ve the final impression upon the reader's mind that, if
ey be not completely answered, they certainly are not
al. Their negative force being thus destroyed, you are
e to be influenced by the vast positive mass of evidence
is able to bring before you. This largeness of knowl-
ge, and readiness of resource, render Mr. Darwin the
ost terrible of antagonists. Accomplished naturalists
ve levelled heavy and sustained criticisms against him
not always with the view of fairly weighing his theory,
t with the express intention of exposing its weak points
ly. This does not irritate him. He treats every objec-
n with a soberness and thoroughness which even Bishop
ıtler might be proud to imitate, surrounding each fact
th its appropriate detail, placing it in its proper rela-
ns, and usually giving it a significance which, as long
it was kept isolated, failed to appear. This is done
thout a trace of ill-temper. He moves over the subject
th the passionless strength of a glacier; and the grind-

ing of the rocks is not always without a counterpart i the logical pulverization of the objector. But though i handling this mighty theme all passion has been stilled there is an emotion of the intellect, incident to the dis cernment of new truth, which often colors and warms th pages of Mr. Darwin. His success has been great; and this implies not only the solidity of his work, but the pre paredness of the public mind for such a revelation. O this head, a remark of Agassiz impressed me more tha anything else. Sprung from a race of theologians, thi celebrated man combated to the last the theory of natura selection. One of the many times I had the pleasure o meeting him in the United States was at Mr. Winthrop' beautiful residence at Brookline, near Boston. Rising from luncheon, we all halted, as if by common consent in front of a window, and continued there a discussion which had been started at table. The maple was in it autumn glory, and the exquisite beauty of the scene out side seemed, in my case, to interpenetrate without disturb ance the intellectual action. Earnestly, almost sadly, Agas siz turned, and said to the gentlemen standing round, " confess that I was not prepared to see this theory receive as it has been by the best intellects of our time. Its suc cess is greater than I could have thought possible."

§ 7

In our day grand generalizations have been reached The theory of the origin of species is but one of them Another, of still wider grasp and more radical signifi cance, is the doctrine of the Conservation of Energy, th ultimate philosophical issues of which are as yet bu dimly seen—that doctrine which "binds nature fast i

e," to an extent not hitherto recognized, exacting from
ry antecedent its equivalent consequent, from every
sequent its equivalent antecedent, and bringing vital
well as physical phenomena under the dominion of
t law of causal connection which, so far as the human
lerstanding has yet pierced, asserts itself everywhere
nature. Long in advance of all definite experiment
on the subject, the constancy and indestructibility of
tter had been affirmed; and all subsequent experience
tified the affirmation. Mayer extended the attribute of
estructibility to energy, applying it in the first instance
inorganic,[1] and afterward with profound insight to or-
ic nature. The vegetable world, though drawing all
nutriment from invisible sources, was proved incom-
ent to generate anew either matter or force. Its mat-
is for the most part transmuted gas; its force trans-
med solar force. The animal world has proved to be
ally uncreative, all its motive energies being referred
the combustion of its food. The activity of each ani-
l, as a whole, was proved to be the transferred activity
ts molecules. The muscles were shown to be stores of
chanical energy, potential until unlocked by the nerves,
l then resulting in muscular contractions. The speed
which messages fly to and fro along the nerves was de-
mined by Helmholtz, and found to be, not, as had been
viously supposed, equal to that of light or electricity,
less than the speed of sound—less even than that of
eagle.

This was the work of the physicist: then came the

Dr. Berthold has shown that Leibnitz had sound views regarding the
ervation of energy in inorganic nature.

revealing the structure of every animal, and the function of every organ in the whole biological series, from the lowest zoophyte up to man. The nervous system had been made the object of profound and continued study, the wonderful and, at bottom, entirely mysterious controlling power which it exercises over the whole organism, physical and mental, being recognized more and more. Thought could not be kept back from a subject so profoundly suggestive. Besides the physical life dealt with by Mr. Darwin, there is a psychical life presenting similar gradations, and asking equally for a solution. How are the different grades and orders of Mind to be accounted for? What is the principle of growth of that mysterious power which on our planet culminates in Reason? These are questions which, though not thrusting themselves so forcibly upon the attention of the general public, had not only occupied many reflecting minds, but had been formally broached by one of them before the "Origin of Species" appeared.

With the mass of materials furnished by the physicist and physiologist in his hands, Mr. Herbert Spencer, twenty years ago, sought to graft upon this basis a system of psychology; and two years ago a second and greatly amplified edition of his work appeared. Those who have occupied themselves with the beautiful experiments of Plateau will remember that when two spherules of olive oil, suspended in a mixture of alcohol and water of the same density as the oil, are brought together, they do not immediately unite. Something like a pellicle appears to be formed around the drops, the rupture of which is immediately followed by the coalescence of the globules into

one. There are organisms whose vital actions are almost as purely physical as the coalescence of such drops of oil. They come into contact and fuse themselves thus together. From such organisms to others a shade higher, from these to others a shade higher still, and on through an ever-ascending series, Mr. Spencer conducts his argument. There are two obvious factors to be here taken into account—the creature and the medium in which it lives, or, as it is often expressed, the organism and its environment. Mr. Spencer's fundamental principle is, that between these two factors there is incessant interaction. The organism is played upon by the environment, and is modified to meet the requirements of the environment. Life he defines to be "a continuous adjustment of internal relations to external relations."

In the lowest organisms we have a kind of tactual sense diffused over the entire body; then, through impressions from without and their corresponding adjustments, special portions of the surface become more responsive to stimuli than others. The senses are nascent, the basis of all of them being that simple tactual sense which the sage Democritus recognized 2,300 years ago as their common progenitor. The action of light, in the first instance, appears to be a mere disturbance of the chemical processes in the animal organism, similar to that which occurs in the leaves of plants. By degrees the action becomes localized in a few pigment-cells, more sensitive to light than the surrounding tissue. The eye is incipient. At first it is merely capable of revealing differences of light and shade produced by bodies close at hand. Followed, as the interception of the light commonly is, by the contact of the closely adjacent opaque body, sight in

this condition becomes a kind of "anticipatory touch." The adjustment continues; a slight bulging out of the epidermis over the pigment-granules supervenes. A lens is incipient, and, through the operation of infinite adjustments, at length reaches the perfection that it displays in the hawk and eagle. So of the other senses; they are special differentiations of a tissue which was originally vaguely sensitive all over.

With the development of the senses, the adjustments between the organism and its environment gradually extend in *space*, a multiplication of experiences and a corresponding modification of conduct being the result. The adjustments also extend in *time*, covering continually greater intervals. Along with this extension in space and time the adjustments also increase in speciality and complexity, passing through the various grades of brute life, and prolonging themselves into the domain of reason. Very striking are Mr. Spencer's remarks regarding the influence of the sense of touch upon the development of intelligence. This is, so to say, the mother-tongue of all the senses, into which they must be translated to be of service to the organism. Hence its importance. The parrot is the most intelligent of birds, and its tactual power is also greatest. From this sense it gets knowledge, unattainable by birds which cannot employ their feet as hands. The elephant is the most sagacious of quadrupeds—its tactual range and skill, and the consequent multiplication of experiences, which it owes to its wonderfully adaptable trunk, being the basis of its sagacity. Feline animals, for a similar cause, are more sagacious than hoofed animals—atonement being to some extent made, in the case of the horse, by the possession of

sensitive prehensile lips. In the *Primates* the evolution of intellect and the evolution of tactual appendages go hand in hand. In the most intelligent anthropoid apes we find the tactual range and delicacy greatly augmented, new avenues of knowledge being thus opened to the animal. Man crowns the edifice here, not only in virtue of his own manipulatory power, but through the enormous extension of his range of experience, by the invention of instruments of precision, which serve as supplemental senses and supplemental limbs. The reciprocal action of these is finely described and illustrated. That chastened intellectual emotion to which I have referred in connection with Mr. Darwin is not absent in Mr. Spencer. His illustrations possess at times exceeding vividness and force; and from his style on such occasions it is to be inferred that the ganglia of this Apostle of the Understanding are sometimes the seat of a nascent poetic thrill.

It is a fact of supreme importance that actions, the performance of which at first requires even painful effort and deliberation, may, by habit, be rendered automatic. Witness the slow learning of its letters by a child, and the subsequent facility of reading in a man, when each group of letters which forms a word is instantly, and without effort, fused to a single perception. Instance the billiard-player, whose muscles of hand and eye, when he reaches the perfection of his art, are unconsciously coordinated. Instance the musician who, by practice, is enabled to fuse a multitude of arrangements, auditory, tactual, and muscular, into a process of automatic manipulation. Combining such facts with the doctrine of hereditary transmission, we reach a theory of Instinct. A chick, after coming out of the egg, balances itself correctly, runs

about, picks up food, thus showing that it possesses a power of directing its movements to definite ends. How did the chick learn this very complex co-ordination of eyes, muscles, and beak? It has not been individually taught; its personal experience is *nil;* but it has the benefit of ancestral experience. In its inherited organization are registered the powers which it displays at birth. So also as regards the instinct of the hive-bee, already referred to. The distance at which the insects stand apart when they sweep their hemispheres and build their cells is "organically remembered." Man also carries with him the physical texture of his ancestry, as well as the inherited intellect bound up with it. The defects of intelligence during infancy and youth are probably less due to a lack of individual experience than to the fact that in early life the cerebral organization is still incomplete. The period necessary for completion varies with the race, and with the individual. As a round shot outstrips the rifled bolt on quitting the muzzle of the gun, so the lower race, in childhood, may outstrip the higher. But the higher eventually overtakes the lower, and surpasses it in range. As regards individuals, we do not always find the precocity of youth prolonged to mental power in maturity; while the dulness of boyhood is sometimes strikingly contrasted with the intellectual energy of after years. Newton, when a boy, was weakly, and he showed no particular aptitude at school; but in his eighteenth year he went to Cambridge, and soon afterward astonished his teachers by his power of dealing with geometrical problems. During his quiet youth his brain was slowly preparing itself to be the organ of those energies which he subsequently displayed.

By myriad blows (to use a Lucretian phrase) the image nd superscription of the external world are stamped as tates of consciousness upon the organism, the depth of he impression depending on the number of the blows. When two or more phenomena occur in the environment nvariably together, they are stamped to the same depth r to the same relief, and indissolubly connected. And ere we come to the threshold of a great question. Seeng that he could in no way rid himself of the consciousess of Space and Time, Kant assumed them to be necssary "forms of intuition," the molds and shapes into which our intuitions are thrown belonging to ourselves, nd without objective existence. With unexpected power nd success, Mr. Spencer brings the hereditary experience heory, as he holds it, to bear upon this question. "If here exist certain external relations which are experienced y all organisms at all instants of their waking lives—relations which are absolutely constant and universal—there will be established answering internal relations that are bsolutely constant and universal. Such relations we ave in those of Space and Time. As the substratum f all other relations of the Non-ego, they must be responded to by conceptions that are the substrata of all ther relations in the Ego. Being the constant and infiitely repeated elements of thought, they must become the utomatic elements of thought—the elements of thought which it is impossible to get rid of—the 'forms of intuiion.'"

Throughout this application and extension of Hartley's nd Mill's "Law of Inseparable Association," Mr. Spencer tands upon his own ground, invoking, instead of the exeriences of the individual, the registered experiences of

the race. His overthrow of the restriction of experience to the individual is, I think, complete. That restriction ignores the power of organizing experience, furnished at the outset to each individual; it ignores the different degrees of this power possessed by different races, and by different individuals of the same race. Were there not in the human brain a potency antecedent to all experience, a dog or a cat ought to be as capable of education as a man. These predetermined internal relations are independent of the experiences of the individual. The human brain is the "organized register of infinitely numerous experiences received during the evolution of life, or rather during the evolution of that series of organisms through which the human organism has been reached. The effects of the most uniform and frequent of these experiences have been successively bequeathed, principal and interest, and have slowly mounted to that high intelligence which lies latent in the brain of the infant. Thus it happens that the European inherits from twenty to thirty cubic inches more of brain than the Papuan. Thus it happens that faculties, as of music, which scarcely exist in some inferior races, become congenital in superior ones. Thus it happens that out of savages unable to count up to the number of their fingers, and speaking a language containing only nouns and verbs, arise at length our Newtons and Shakespeares."

§ 8

At the outset of this Address it was stated that physical theories which lie beyond experience are derived by a process of abstraction from experience. It is instructive to note from this point of view the successive introduction

f new conceptions. The idea of the attraction of gravitaion was preceded by the observation of the attraction of ron by a magnet, and of light bodies by rubbed amber. 'he polarity of magnetism and electricity also appealed to he senses. It thus became the substratum of the conception that atoms and molecules are endowed with attractive nd repellent poles, by the play of which definite forms f crystalline architecture are produced. Thus molecular orce becomes *structural.*[1] It required no great boldness f thought to extend its play into organic nature, and to ecognize in molecular force the agency by which both lants and animals are built up. In this way, out of experience arise conceptions which are wholly ultra-experintial. None of the atomists of antiquity had any notion f this play of molecular polar force, but they had experince of gravity, as manifested by falling bodies. Abstracting from this, they permitted their atoms to fall eternally hrough empty space. Democritus assumed that the larger toms moved more rapidly than the smaller ones, which hey therefore could overtake, and with which they could ombine. Epicurus, holding that empty space could offer o resistance to motion, ascribed to all the atoms the same elocity; but he seems to have overlooked the conseuence that under such circumstances the atoms could ever combine. Lucretius cut the knot by quitting the lomain of physics altogether, and causing the atoms to nove together by a kind of volition.

Was the instinct utterly at fault which caused Lucreius thus to swerve from his own principles? Diminishng gradually the number of progenitors, Mr. Darwin

[1] See Art. on Matter and Force, or "Lectures on Light," No. III.

comes at length to one "primordial form"; but he does not say, so far as I remember, how he supposes this form to have been introduced. He quotes with satisfaction the words of a celebrated author and divine who had "gradually learned to see that it was just as noble a conception of the Deity to believe He created a few original forms, capable of self-development into other and needful forms, as to believe He required a fresh act of creation to supply the voids caused by the action of His laws." What Mr. Darwin thinks of this view of the introduction of life I do not know. But the anthropomorphism, which it seemed his object to set aside, is as firmly associated with the creation of a few forms as with the creation of a multitude. We need clearness and thoroughness here. Two courses and two only are possible. Either let us open our doors freely to the conception of creative acts, or abandoning them, let us radically change our notions of Matter. If we look at matter as pictured by Democritus, and as defined for generations in our scientific text-books, the notion of conscious life coming out of it cannot be formed by the mind. The argument placed in the mouth of Bishop Butler suffices, in my opinion, to crush all such materialism as this. Those, however, who framed these definitions of matter were but partial students. They were not biologists, but mathematicians, whose labors referred only to such accidents and properties of matter as could be expressed in their formulæ. Their science was mechanical science, not the science of life. With matter in its wholeness they never dealt; and, denuded by their imperfect definitions, "the gentle mother of all" became the object of her children's dread. Let us reverently, but honestly, look the question

in the face. Divorced from matter, where is life? Whatever our *faith* may say, our *knowledge* shows them to be indissolubly joined. Every meal we eat, and every cup we drink, illustrates the mysterious control of Mind by Matter.

On tracing the line of life backward, we see it approaching more and more to what we call the purely physical condition. We come at length to those organisms which I have compared to drops of oil suspended in a mixture of alcohol and water. We reach the *protogenes* of Haeckel, in which we have "a type distinguishable from a fragment of albumen only by its finely granular character." Can we pause here? We break a magnet, and find two poles in each of its fragments. We continue the process of breaking; but, however small the parts, each carries with it, though enfeebled, the polarity of the whole. And when we can break no longer, we prolong the intellectual vision to the polar molecules. Are we not urged to do *something* similar in the case of life? Is there not a temptation to close to some extent with Lucretius, when he affirms that "Nature is seen to do all things spontaneously of herself without the meddling of the gods?" or with Bruno, when he declares that Matter is not "that mere empty *capacity* which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her own womb?" Believing, as I do, in the continuity of nature, I cannot stop abruptly where our microscopes cease to be of use. Here the vision of the mind authoritatively supplements the vision of the eye. By a necessity engendered and justified by science I cross the boundary of the experimental evidence,[1] and discern in that Matter which we, in our

[1] This mode of procedure was not invented in Belfast.

ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of all terrestrial Life.

If you ask me whether there exists the least evidence to prove that any form of life can be developed out of matter, without demonstrable antecedent life, my reply is that evidence considered perfectly conclusive by many has been adduced; and that were some of us who have pondered this question to follow a very common example, and accept testimony because it falls in with our belief, we also should eagerly close with the evidence referred to. But there is in the true man of science a desire stronger than the wish to have his beliefs upheld; namely, the desire to have them true. And this stronger wish causes him to reject the most plausible support, if he has reason to suspect that it is vitiated by error. Those to whom I refer as having studied this question, believing the evidence offered in favor of "spontaneous generation" to be thus vitiated, cannot accept it. They know full well that the chemist now prepares from inorganic matter a vast array of substances, which were some time ago regarded as the sole products of vitality. They are intimately acquainted with the structural power of matter, as evidenced in the phenomena of crystallization. They can justify scientifically their *belief* in its potency, under the proper conditions, to produce organisms. But, in reply to your questions, they will frankly admit their inability to point to any satisfactory experimental proof that life can be developed, save from demonstrable antecedent life. As already indicated, they draw the line from the highest organisms through lower ones down to the lowest; and

it is the prolongation of this line by the intellect, beyond the range of the senses, that leads them to the conclusion which Bruno so boldly enunciated.[1]

The "materialism" here professed may be vastly different from what you suppose, and I therefore crave your gracious patience to the end. "The question of an external world," says J. S. Mill, "is the great battleground of metaphysics."[2] Mr. Mill himself reduces external phenomena to "possibilities of sensation." Kant, as we have seen, made time and space "forms" of our own intuitions. Fichte, having first by the inexorable logic of his understanding proved himself to be a mere link in that chain of eternal causation which holds so rigidly in nature, violently broke the chain by making nature, and all that it inherits, an apparition of the mind.[3] And it is by no means easy to combat such notions. For when I say "I see you," and that there is not the least doubt about it, the obvious reply is, that what I am really conscious of is an affection of my own retina. And if I urge that my sight can be checked by touching you, the retort would be that I am equally transgressing the limits of fact; for what I am really conscious of is, not that you are there, but that the nerves of my hand have undergone a change. All we hear, and see, and touch, and taste, and smell, are, it would be urged, mere variations of our own condition, beyond which, even to the extent of a hair-breadth, we cannot go. That anything answering to our impressions exists outside of ourselves is not a *fact*, but an *inference*, to which all validity would be denied by

[1] Bruno was a "Pantheist," not an "Atheist" or a "Materialist."
[2] "Examination of Hamilton," p. 154.
[3] "Bestimmung des Menschen."

an idealist like Berkeley, or by a sceptic like Hume. Mr. Spencer takes another line. With him, as with the uneducated man, there is no doubt or question as to the existence of an external world. But he differs from the uneducated, who think that the world really *is* what consciousness represents it to be. Our states of consciousness are mere *symbols* of an outside entity which produces them and determines the order of their succession, but the real nature of which we can never know.[1] In fact, the whole process of evolution is the manifestation of a Power absolutely inscrutable to the intellect of man. As little in our day as in the days of Job can man by searching find this Power out. Considered fundamentally, then, it is by the operation of an insoluble mystery that life on earth is evolved, species differentiated, and mind unfolded, from their prepotent elements in the immeasurable past.

The strength of the doctrine of Evolution consists, not in an experimental demonstration (for the subject is hardly accessible to this mode of proof), but in its general harmony with scientific thought. From contrast, moreover, it derives enormous relative cogency. On the one side

[1] In a paper, at once popular and profound, entitled "Recent Progress in the Theory of Vision," contained in the volume of lectures by Helmholtz, published by Longmans, this symbolism of our states of consciousness is also dwelt upon. The impressions of sense are the mere *signs* of external things. In this paper Helmholtz contends strongly against the view that the consciousness of space is inborn; and he evidently doubts the power of the chick to pick up grains of corn without preliminary lessons. On this point, he says, further experiments are needed. Such experiments have been since made by Mr. Spalding, aided, I believe, in some of his observations by the accomplished and deeply lamented Lady Amberly; and they seem to prove conclusively that the chick does not need a single moment's tuition to enable it to stand, run, govern the muscles of its eyes, and peck. Helmholtz, however, is contending against the notion of pre-established harmony; and I am not aware of his views as to the organization of experiences of race or breed.

we have a theory (if it could with any propriety be so called) derived, as were the theories referred to at the beginning of this Address, not from the study of nature, but from the observation of men—a theory which converts the Power whose garment is seen in the visible universe into an Artificer, fashioned after the human model, and acting by broken efforts as man is seen to act. On the other side we have the conception that all we see around us, and all we feel within us—the phenomena of physical nature as well as those of the human mind—have their unsearchable roots in a cosmical life, if I dare apply the term, an infinitesimal span of which is offered to the investigation of man. And even this span is only knowable in part. We can trace the development of a nervous system, and correlate with it the parallel phenomena of sensation and thought. We see with undoubting certainty that they go hand in hand. But we try to soar in a vacuum the moment we seek to comprehend the connection between them. An Archimedean fulcrum is here required which the human mind cannot command; and the effort to solve the problem—to borrow a comparison from an illustrious friend of mine—is like that of a man trying to lift himself by his own waistband. All that has been said in this discourse is to be taken in connection with this fundamental truth. When "nascent senses" are spoken of, when "the differentiation of a tissue at first vaguely sensitive all over" is spoken of, and when these possessions and processes are associated with "the modification of an organism by its environment," the same parallelism, without contact, or even approach to contact, is implied. Man the *object* is separated by an impassable gulf from man the *subject*. There is no motor energy in

the human intellect to carry it, without logical rupture, from the one to the other.

§ 9

The doctrine of Evolution derives man, in his totality, from the interaction of organism and environment through countless ages past. The Human Understanding, for example—that faculty which Mr. Spencer has turned so skilfully round upon its own antecedents—is itself a result of the play between organism and environment through cosmic ranges of time. Never, surely, did prescription plead so irresistible a claim. But then it comes to pass that, over and above his understanding, there are many other things appertaining to man, whose prescriptive rights are quite as strong as those of the understanding itself. It is a result, for example, of the play of organism and environment that sugar is sweet, and that aloes are bitter; that the smell of henbane differs from the perfume of a rose. Such facts of consciousness (for which, by the way, no adequate reason has ever been rendered) are quite as old as the understanding; and many other things can boast an equally ancient origin. Mr. Spencer at one place refers to that most powerful of passions—the amatory passion—as one which, when it first occurs, is antecedent to all relative experience whatever; and we may press its claim as being at least as ancient, and as valid, as that of the understanding itself. Then there are such things woven into the texture of man as the feeling of Awe, Reverence, Wonder—and not alone the sexual love just referred to, but the love of the beautiful, physical, and moral, in Nature, Poetry, and Art. There is also that deep-set feeling, which, since the earliest dawn of history, and probably

for ages prior to all history, incorporated itself in the Religions of the world. You, who have escaped from these religions into the high-and-dry light of the intellect, may deride them; but in so doing you deride accidents of form merely, and fail to touch the immovable basis of the religious sentiment in the nature of man. To yield this sentiment reasonable satisfaction is the problem of problems at the present hour. And grotesque in relation to scientific culture as many of the religions of the world have been and are—dangerous, nay, destructive, to the dearest privileges of freemen as some of them undoubtedly have been, and would, if they could, be again—it will be wise to recognize them as the forms of a force, mischievous if permitted to intrude on the region of objective *knowledge*, over which it holds no command, but capable of adding, in the region of *poetry* and *emotion*, inward completeness and dignity to man.

Feeling, I say again, dates from as old an origin and as high a source as intelligence, and it equally demands its range of play. The wise teacher of humanity will recognize the necessity of meeting this demand, rather than of resisting it on account of errors and absurdities of form. What we should resist, at all hazards, is the attempt made in the past, and now repeated, to found upon this elemental bias of man's nature a system which should exercise despotic sway over his intellect. I have no fear of such a consummation. Science has already to some extent leavened the world; it will leaven it more and more. I should look upon the mild light of science breaking in upon the minds of the youth of Ireland, and strengthening gradually to the perfect day, as a surer check to any intellectual or spiritual tyranny which may

threaten this island, than the laws of princes or the swords of emperors. We fought and won our battle even in the Middle Ages: should we doubt the issue of another conflict with our broken foe?

The impregnable position of science may be described in a few words. We claim, and we shall wrest from theology, the entire domain of cosmological theory. All schemes and systems which thus infringe upon the domain of science must, in so far as they do this, submit to its control, and relinquish all thought of controlling it. Acting otherwise proved always disastrous in the past, and it is simply fatuous to-day. Every system which would escape the fate of an organism too rigid to adjust itself to its environment, must be plastic to the extent that the growth of knowledge demands. When this truth has been thoroughly taken in, rigidity will be relaxed, exclusiveness diminished, things now deemed essential will be dropped, and elements now rejected will be assimilated. The lifting of the life is the essential point; and as long as dogmatism, fanaticism, and intolerance are kept out, various modes of leverage may be employed to raise life to a higher level.

Science itself not infrequently derives motive power from an ultra-scientific source. Some of its greatest discoveries have been made under the stimulus of a non-scientific ideal. This was the case among the ancients, and it has been so among ourselves. Mayer, Joule, and Colding, whose names are associated with the greatest of modern generalizations, were thus influenced. With his usual insight, Lange at one place remarks that "it is not always the objectively correct and intelligible that helps man most, or leads most quickly to the fullest and truest

knowledge. As the sliding body upon the brachystochrone reaches its end sooner than by the straighter road of the inclined plane, so, through the swing of the ideal, we often arrive at the naked truth more rapidly than by the processes of the understanding." Whewell speaks of enthusiasm of temper as a hinderance to science; but he means the enthusiasm of weak heads. There is a strong and resolute enthusiasm in which science finds an ally; and it is to the lowering of this fire, rather than to the diminution of intellectual insight, that the lessening productiveness of men of science, in their mature years, is to be ascribed. Mr. Buckle sought to detach intellectual achievement from moral force. He gravely erred, for without moral force to whip it into action, the achievement of the intellect would be poor indeed.

It has been said by its opponents that science divorces itself from literature; but the statement, like so many others, arises from lack of knowledge. A glance at the less technical writings of its leaders—of its Helmholtz, its Huxley, and its Du Bois-Reymond—would show what breadth of literary culture they command. Where among modern writers can you find their superiors in clearness and vigor of literary style? Science desires not isolation, but freely combines with every effort toward the bettering of man's estate. Single-handed, and supported, not by outward sympathy, but by inward force, it has built at least one great wing of the many-mansioned home which man in his totality demands. And if rough walls and protruding rafter-ends indicate that on one side the edifice is still incomplete, it is only by wise combination of the parts required, with those already irrevocably built, that we can hope for completeness. There is no neces-

sary incongruity between what has been accomplished and what remains to be done. The moral glow of Socrates, which we all feel by ignition, has in it nothing incompatible with the physics of Anaxagoras which he so much scorned, but which he would hardly scorn to-day. And here I am reminded of one among us, hoary, but still strong, whose prophet-voice some thirty years ago, far more than any other of this age, unlocked whatever of life and nobleness lay latent in its most gifted minds—one fit to stand beside Socrates or the Maccabean Eleazar, and to dare and suffer all that they suffered and dared—fit, as he once said of Fichte, "to have been the teacher of the Stoa, and to have discoursed of Beauty and Virtue in the groves of Academe." With a capacity to grasp physical principles which his friend Goethe did not possess, and which even total lack of exercise has not been able to reduce to atrophy, it is the world's loss that he, in the vigor of his years, did not open his mind and sympathies to science, and make its conclusions a portion of his message to mankind. Marvellously endowed as he was—equally equipped on the side of the Heart and of the Understanding—he might have done much toward teaching us how to reconcile the claims of both, and to enable them in coming times to dwell together, in unity of spirit and in the bond of peace.

And now the end is come. With more time, or greater strength and knowledge, what has been here said might have been better said, while worthy matters, here omitted, might have received fit expression. But there would have been no material deviation from the views set forth. As regards myself, they are not the growth

a day; and as regards you, I thought you ought to
ow the environment which, with or without your con-
t, is rapidly surrounding you, and in relation to which
ne adjustment on your part may be necessary. A hint
Hamlet's, however, teaches us how the troubles of com-
n life may be ended; and it is perfectly possible for
a and me to purchase intellectual peace at the price
intellectual death. The world is not without refuges of
s description; nor is it wanting in persons who seek
ir shelter, and try to persuade others to do the same.
e unstable and the weak have yielded and will yield to
s persuasion, and they to whom repose is sweeter than
truth. But I would exhort you to refuse the offered
lter, and to scorn the base repose—to accept, if the
ice be forced upon you, commotion before stagnation,
breezy leap of the torrent before the fetid stillness of
swamp. In the course of this Address I have touched
debatable questions, and led you over what will be
med dangerous ground—and this partly with the view
telling you that, as regards these questions, science
ms unrestricted right of search. It is not to the point
say that the views of Lucretius and Bruno, of Darwin
Spencer, may be wrong. Here I should agree with
a, deeming it indeed certain that these views will un-
go modification. But the point is that, whether right
wrong, we claim the right to discuss them. For
nce, however, no exclusive claim is here made; you
not urged to erect it into an idol. The inexorable
ance of man's understanding in the path of knowl
e, and those unquenchable claims of his moral and
otional nature, which the understanding can never sat-
, are here equally set forth. The world embraces not

only a Newton, but a Shakespeare—not only a Boyle, but a Raphael—not only a Kant, but a Beethoven—not only a Darwin, but a Carlyle. Not in each of these, but in all, is human nature whole. They are not opposed, but supplementary—not mutually exclusive, but reconcilable. And if, unsatisfied with them all, the human mind, with the yearning of a pilgrim for his distant home, will still turn to the Mystery from which it has emerged, seeking so to fashion it as to give unity to thought and faith; so long as this is done, not only without intolerance or bigotry of any kind, but with the enlightened recognition that ultimate fixity of conception is here unattainable, and that each succeeding age must be held free to fashion the mystery in accordance with its own needs—then, casting aside all the restrictions of Materialism, I would affirm this to be a field for the noblest exercise of what, in contrast with the *knowing* faculties, may be called the *creative* faculties of man. Here, however, I touch a theme too great for me to handle, but which will assuredly be handled by the loftiest minds, when you and I, like streaks of morning cloud, shall have melted into the infinite azure of the past.

nature be the really potent factor, we may expect utterances as heterogeneous as the characters of men. As a matter of fact we have the latter; suggesting to my mind that the common religion, professed and defended by these different people, is merely the accidental conduit through which they pour their own tempers, lofty or low, courteous or vulgar, mild or ferocious, as the case may be. Pure abuse, however, as serving no good end, I have, wherever possible, deliberately avoided reading, wishing, indeed, to keep, not only hatred, malice, and uncharitableness, but even every trace of irritation, far away from my side of a discussion which demands not only good-temper, but largeness, clearness, and many-sidedness of mind, if it is to guide us to even provisional solutions.

It has been stated, with many variations of note and comment, that in the Address as subsequently published by Messrs. Longman I have retracted opinions uttered at Belfast. A Roman Catholic writer is specially strong upon this point. Startled by the deep chorus of dissent which my "dazzling fallacies" have evoked, I am now trying to retreat. This he will by no means tolerate. "It is too late now to seek to hide from the eyes of mankind one foul blot, one ghastly deformity. Professor Tyndall has himself told us how and where this Address of his was composed. It was written among the glaciers and the solitudes of the Swiss mountains. It was no hasty, hurried, crude production; its every sentence bore marks of thought and care."

My critic intends to be severe: he is simply just. In the "solitudes" to which he refers I worked with deliberation, endeavoring even to purify my intellect by disciplines similar to those enjoined by his own Church for

the sanctification of the soul. I tried, moreover, in my ponderings to realize not only the lawful, but the expedient; and to permit no fear to act upon my mind, save that of uttering a single word on which I could not take my stand, either in this or in any other world.

Still my time was so brief, the difficulties arising from my isolated position were so numerous, and my thought and expression so slow, that, in a literary point of view, I halted, not only behind the ideal, but behind the possible. Hence, after the delivery of the Address, I went over it with the desire, not to revoke its principles, but to improve it verbally, and above all to remove any word which might give color to the notion of "crudeness, hurry, or haste."

In connection with the charge of Atheism my critic refers to the Preface to the second issue of the Belfast Address: "Christian men," I there say, "are proved by their writings to have their hours of weakness and of doubt, as well as their hours of strength and of conviction; and men like myself share, in their own way, these variations of mood and tense. Were the religious moods of many of my assailants the only alternative ones, I do not know how strong the claims of the doctrine of 'Material Atheism' upon my allegiance might be. Probably they would be very strong. But, as it is, I have noticed during years of self-observation that it is not in hours of clearness and vigor that this doctrine commends itself to my mind; that in the presence of stronger and healthier thought it ever dissolves and disappears, as offering no solution of the mystery in which we dwell, and of which we form a part."

With reference to this honest and reasonable utterance

nature be the really potent factor, we may expect utterances as heterogeneous as the characters of men. As a matter of fact we have the latter; suggesting to my mind that the common religion, professed and defended by these different people, is merely the accidental conduit through which they pour their own tempers, lofty or low, courteous or vulgar, mild or ferocious, as the case may be. Pure abuse, however, as serving no good end, I have, wherever possible, deliberately avoided reading, wishing, indeed, to keep, not only hatred, malice, and uncharitableness, but even every trace of irritation, far away from my side of a discussion which demands not only good-temper, but largeness, clearness, and many-sidedness of mind, if it is to guide us to even provisional solutions.

It has been stated, with many variations of note and comment, that in the Address as subsequently published by Messrs. Longman I have retracted opinions uttered at Belfast. A Roman Catholic writer is specially strong upon this point. Startled by the deep chorus of dissent which my "dazzling fallacies" have evoked, I am now trying to retreat. This he will by no means tolerate. "It is too late now to seek to hide from the eyes of mankind one foul blot, one ghastly deformity. Professor Tyndall has himself told us how and where this Address of his was composed. It was written among the glaciers and the solitudes of the Swiss mountains. It was no hasty, hurried, crude production; its every sentence bore marks of thought and care."

My critic intends to be severe: he is simply just. In the "solitudes" to which he refers I worked with deliberation, endeavoring even to purify my intellect by disciplines similar to those enjoined by his own Church for

the sanctification of the soul. I tried, moreover, in my ponderings to realize not only the lawful, but the expedient; and to permit no fear to act upon my mind, save that of uttering a single word on which I could not take my stand, either in this or in any other world.

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my censor exclaims, "This is a most remarkable passage. Much as we dislike seasoning polemics with strong words, we assert that this Apology only tends to affix with links of steel to the name of Professor Tyndall the dread imputation against which he struggles."

Here we have a very fair example of subjective religious vigor. But my quarrel with such exhibitions is that they do not always represent objective fact. No atheistic reasoning can, I hold, dislodge religion from the human heart. Logic cannot deprive us of life, and religion is life to the religious. As an experience of consciousness it is beyond the assaults of logic. But the religious life is often projected in external forms—I use the word in its widest sense—and this embodiment of the religious sentiment will have to bear more and more, as the world becomes more enlightened, the stress of scientific tests. We must be careful of projecting into external nature that which belongs to ourselves. My critic commits this mistake: he feels, and takes delight in feeling, that I am struggling, and he obviously experiences the most exquisite pleasures of "the muscular sense" in holding me down. His feelings are as real as if his imagination of what mine are were equally real. His picture of my "struggles" is, however, a mere delusion. I do not struggle. I do not fear the charge of Atheism; nor should I even disavow it, in reference to any definition of the Supreme which he, or his order, would be likely to frame. His "links" and his "steel" and his "dread imputations" are, therefore, even more unsubstantial than my "streaks of morning cloud," and they may be permitted to vanish together.

These minor and more purely personal matters at an end, the weightier allegation remains that at Belfast I misused my position by quitting the domain of science, and making an unjustifiable raid into the domain of theology. This I fail to see. Laying aside abuse, I hope my accusers will consent to reason with me. Is it not lawful for a scientific man to speculate on the antecedents of the solar system? Did Kant, Laplace, and William Herschel quit their legitimate spheres, when they prolonged the intellectual vision beyond the boundary of experience, and propounded the nebular theory? Accepting that theory as probable, is it not permitted to a scientific man to follow up, in idea, the series of changes associated with the condensation of the nebulæ; to picture the successive detachment of planets and moons, and the relation of all of them to the sun? If I look upon our earth, with its orbital revolution and axial rotation, as one small issue of the process which made the solar system what it is, will any theologian deny my right to entertain and express this theoretic view? Time was when a multitude of theologians would have been found to do so—when that arch-enemy of science which now vaunts its tolerance would have made a speedy end of the man who might venture to publish any opinion of the kind. But that time, unless the world is caught strangely slumbering, is forever past.

As regards inorganic nature, then, we may traverse, without let or hinderance, the whole distance which separates the nebulæ from the worlds of to-day. But only a few years ago this now conceded ground of science was theological ground. I could by no means regard this as the final and sufficient concession of theology; and, at

Belfast, I thought it not only my right, but my duty, to state that, as regards the organic world, we must enjoy the freedom which we have already won in regard to the inorganic. I could not discern the shred of a title-deed which gave any man, or any class of men, the right to open the door of one of these worlds to the scientific searcher and to close the other against him. And I considered it frankest, wisest, and in the long run most conducive to permanent peace, to indicate, without evasion or reserve, the ground that belongs to Science, and to which she will assuredly make good her claim.

I have been reminded that an eminent predecessor of mine in the Presidential chair expressed a totally different view of the Cause of things from that enunciated by me. In doing so he transgressed the bounds of science at least as much as I did; but nobody raised an outcry against him. The freedom he took I claim. And looking at what I must regard as the extravagances of the religious world; at the very inadequate and foolish notions concerning this universe which are entertained by the majority of our authorized religious teachers; at the waste of energy on the part of good men over things unworthy, if I may say it without discourtesy, of the attention of enlightened heathens; the fight about the fripperies of Ritualism, and the verbal quibbles of the Athanasian Creed; the forcing on the public view of Pontigny Pilgrimages; the dating of historic epochs from the definition of the Immaculate Conception; the proclamation of the Divine Glories of the Sacred Heart—standing in the midst of these chimeras, which astound all thinking men, it did not appear to me extravagant to claim the public tolerance for an hour and a half, for the statement of more

reasonable views—views more in accordance with the verities which science has brought to light, and which many weary souls would, I thought, welcome with gratification and relief.

But to come to closer quarters. The expression to which the most violent exception has been taken is this: "Abandoning all disguise, the confession I feel bound to make before you is, that I prolong the vision backward across the boundary of the experimental evidence, and discern in that Matter which we, in our ignorance, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of every form and quality of life." To call it a "chorus of dissent," as my Catholic critic does, is a mild way of describing the storm of opprobrium with which this statement has been assailed. But the first blast of passion being past, I hope I may again ask my opponents to consent to reason. First of all, I am blamed for crossing the boundary of the experimental evidence. This, I reply, is the habitual action of the scientific mind—at least of that portion of it which applies itself to physical investigation. Our theories of light, heat, magnetism, and electricity, all imply the crossing of this boundary. My paper on the "Scientific Use of the Imagination," and my "Lectures on Light," illustrate this point in the amplest manner; and in the Article entitled "Matter and Force" in the present volume I have sought, incidentally, to make clear, that in physics the experiential incessantly leads to the ultra-experiential; that out of experience there always grows something finer than mere experience, and that in their different powers of ideal extension consists, for the most part, the difference between the great and the medi-

cere investigator. The kingdom of science, then, cometh not by observation and experiment alone, but is completed by fixing the roots of observation and experiment in a region inaccessible to both, and in dealing with which we are forced to fall back upon the picturing power of the mind.

Passing the boundary of experience, therefore, does not, in the abstract, constitute a sufficient ground for censure. There must have been something in my particular mode of crossing it which provoked this tremendous "chorus of dissent."

Let us calmly reason the point out. I hold the nebular theory as it was held by Kant, Laplace, and William Herschel, and as it is held by the best scientific intellects of to-day. According to it, our sun and planets were once diffused through space as an impalpable haze, out of which, by condensation, came the solar system. What caused the haze to condense? Loss of heat. What rounded the sun and planets? That which rounds a tear—molecular force. For eons, the immensity of which overwhelms man's conceptions, the earth was unfit to maintain what we call life. It is now covered with visible living things. They are not formed of matter different from that of the earth around them. They are, on the contrary, bone of its bone, and flesh of its flesh. How were they introduced? Was life implicated in the nebula—as part, it may be, of a vaster and wholly Unfathomable Life; or is it the work of a Being standing outside the nebula, who fashioned it, and vitalized it; but whose own origin and ways are equally past finding out? As far as the eye of science has hitherto ranged through nature, no intrusion of purely creative power into any series of

phenomena has ever been observed. The assumption of such a power to account for special phenomena, though often made, has always proved a failure. It is opposed to the very spirit of science; and I therefore assumed the responsibility of holding up, in contrast with it, that method of nature which it has been the vocation and triumph of science to disclose, and in the application of which we can alone hope for further light. Holding, then, that the nebulæ and the solar system, life included, stand to each other in the relation of the germ to the finished organism, I reaffirm here, not arrogantly, or defiantly, but without a shade of indistinctness, the position laid down at Belfast.

Not with the vagueness belonging to the emotions, but with the definiteness belonging to the understanding, the scientific man has to put to himself these questions regarding the introduction of life upon the earth. He will be the last to dogmatize upon the subject, for he knows best that certainty is here for the present unattainable. His refusal of the creative hypothesis is less an assertion of knowledge than a protest against the assumption of knowledge which must long, if not forever, lie beyond us, and the claim to which is the source of perpetual confusion upon earth. With a mind open to conviction he asks his opponents to show him an authority for the belief they so strenuously and so fiercely uphold. They can do no more than point to the Book of Genesis, or some other portion of the Bible. Profoundly interesting, and indeed pathetic, to me are those attempts of the opening mind of man to appease its hunger for a Cause. But the Book of Genesis has no voice in scientific questions. To the grasp of geology, which it resisted for a time, it at length yielded like potter's clay; its authority as a system of cos-

mogony being discredited on all hands, by the abandonment of the obvious meaning of its writer. It is a poem, not a scientific treatise. In the former aspect it is forever beautiful: in the latter aspect it has been, and it will continue to be, purely obstructive and hurtful. To *knowledge* its value has been negative, leading, in rougher ages than ours, to physical, and even in our own "free" age to moral, violence.

No incident connected with the proceedings at Belfast is more instructive than the deportment of the Catholic hierarchy of Ireland; a body usually too wise to confer notoriety upon an adversary by imprudently denouncing him. The "Times," to which I owe a great deal on the score of fair play, where so much has been unfair, thinks that the Irish Cardinal, Archbishops, and Bishops, in a recent manifesto, adroitly employed a weapon which I, at an unlucky moment, placed in their hands. The antecedents of their action cause me to regard it in a different light; and a brief reference to these antecedents will, I think, illuminate not only their proceedings regarding Belfast, but other doings which have been recently noised abroad.

Before me lies a document bearing the date of November, 1873, which, after appearing for a moment, unaccountably vanished from public view. It is a Memorial addressed, by Seventy of the Students and Ex-students of the Catholic University in Ireland, to the Episcopal Board of the University; and it constitutes the plainest and bravest remonstrance ever addressed by Irish laymen to their spiritual pastors and masters. It expresses the profoundest dissatisfaction with the curriculum marked out for the

udents of the University; setting forth the extraordinary act that the lecture-list for the faculty of Science, published a month before they wrote, did not contain the ame of a single Professor of the Physical or Natural ciences.

The memorialists forcibly deprecate this, and dwell pon the necessity of education in science: "The distinuishing mark of this age is its ardor for science. The atural sciences have, within the last fifty years, become e chiefest study in the world; they are in our time pured with an activity unparalleled in the history of manind. Scarce a year now passes without some discovery eing made in these sciences which, as with the touch of e magician's wand, shivers to atoms theories formerly eemed unassailable. It is through the physical and natral sciences that the fiercest assaults are now made on ur religion. No more deadly weapon is used against our ith than the facts incontestably proved by modern researches in science."

Such statements must be the reverse of comfortable to number of gentlemen who, trained in the philosophy Thomas Aquinas, have been accustomed to the unquesoning submission of all other sciences to their divine sience of Theology. But this is not all: "One thing eems certain," say the memorialists, viz., "that if chairs r the physical and natural sciences be not soon founded the Catholic University, very many young men will ave their faith exposed to dangers which the creation of school of science in the University would defend them om. For our generation of Irish Catholics are writhing nder the sense of their inferiority in science, and are dermined that such inferiority shall not long continue; and

Though molded for centuries to an obedience unparalleled in any other country, except Spain, the Irish intellect is beginning to show signs of independence; demanding a diet more suited to its years than the pabulum of the Middle Ages. As for the recent manifesto in which Pope, Cardinal, Archbishops, and Bishops are united in one grand anathema, its character and fate are shadowed forth by the Vision of Nebuchadnezzar recorded in the Book of Daniel. It resembles the image, whose form was terrible, but the gold, and silver, and brass, and iron of which rested upon feet of clay. And a stone smote the feet of clay; and the iron, and the brass, and the silver, and the gold, were broken in pieces together, and became like the chaff of the summer threshing-floors, and the wind carried them away.

Monsignor Capel has recently been good enough to proclaim at once the friendliness of his Church toward true science, and her right to determine what true science is. Let us dwell for a moment on the proofs of her scientific competence. When Halley's comet appeared in 1456 it was regarded as the harbinger of God's vengeance, the dispenser of war, pestilence, and famine, and by order of the Pope the church bells of Europe were rung to scare the monster away. An additional daily prayer was added to the supplications of the faithful. The comet in due time disappeared, and the faithful were comforted by the assurance that, as in previous instances relating to eclipses, droughts, and rains, so also as regards this "nefarious" comet, victory had been vouchsafed to the Church.

Both Pythagoras and Copernicus had taught the heliocentric doctrine—that the earth revolves round the sun. In the exercise of her right to determine what true science

is, the Church, in the Pontificate of Paul V., stepped in, and by the mouth of the holy Congregation of the Index, delivered, on March 5, 1616, the following decree:

"And whereas it hath also come to the knowledge of the said holy congregation that the false Pythagorean doctrine of the mobility of the earth and the immobility of the sun, entirely opposed to Holy Writ, which is taught by Nicolas Copernicus, is now published abroad and received by many. In order that this opinion may not further spread, to the damage of Catholic truth, it is ordered that this and all other books teaching the like doctrine be suspended, and by this decree they are all respectively suspended, forbidden, and condemned."

But why go back to 1456 and 1616? Far be it from me to charge bygone sins upon Monsignor Capel, were it not for the practices he upholds to-day. The most applauded dogmatist and champion of the Jesuits is, I am informed, Perrone. No less than thirty editions of a work of his have been scattered abroad for the healing of the nations. His notions of physical astronomy are virtually those of 1456. He teaches boldly that "God does not rule by universal law . . . that when God orders a given planet to stand still He does not detract from any law passed by Himself, but orders that planet to move round the sun for such and such a time, then to stand still, and then again to move, as His pleasure may be." Jesuitism proscribed Frohschammer for questioning its favorite dogma, that every human soul was created by a direct supernatural act of God, and for asserting that man, body and soul, came from his parents. This is the system that now strives for universal power; it is from it, as Monsignor

Capel graciously informs us, that we are to learn what is allowable in science, and what is not!

In the face of such facts, which might be multiplied at will, it requires extraordinary bravery of mind, or a reliance upon public ignorance almost as extraordinary, to make the claims made by Monsignor Capel for his Church.

Before me is a very remarkable letter addressed in 1875 by the Bishop of Montpellier to the Deans and Professors of Faculties of Montpellier, in which the writer very clearly lays down the claims of his Church. He had been startled by an incident occurring in a course of lectures on Physiology given by a professor, of whose scientific capacity there was no doubt, but who, it was alleged, rightly or wrongly, had made his course the vehicle of materialism. "Je ne me suis point donné," says the Bishop, "la mission que je remplis au milieu de vous. 'Personne, au temoignage de saint Paul, ne s'attribue à soi-même un pareil honneur; il y faut être appelé de Dieu, comme Aaron.' Et pourquoi en est-il ainsi? C'est parce que, selon le même Apôtre, nous devons être les ambassadeurs de Dieu; et il n'est pas dans les usages, pas plus qu'il n'est dans la raison et le droit, qu'un envoyé s'accrédite lui-meme. Mais, si j'ai reçu d'En-Haut une mission; si l'Eglise, au nom de Dieu lui-même, a souscrit mes lettres de créance, me siérait-il de manquer aux instructions qu'elle m'a données et d'entendre, en un sens différent du sien, le rôle qu'elle m'a confié?

"Or, Messieurs, la sainte Eglise se croit investie du droit absolu d'enseigner les hommes; elle se croit dépositaire de la vérité, non pas de la vérité fragmentaire, incomplète, mêlée de certitude et d'hésitation, mais de la

vérité totale, complète, au point de vue religieux. Bien plus, elle est si sûre de l'infaillibilité que son Fondateur divin lui a communiquée, comme la dot magnifique de leur indissoluble alliance, que, même dans l'ordre naturel, scientifique ou philosophique, moral ou politique, elle n'admet pas qu'un système puisse être soutenu et adopté par des chrétiens, s'il contredit à des dogmes définis. Elle considère que la négation volontaire et opiniâtre d'un seul point de sa doctrine rend coupable du péché d'hérésie; et elle pense que toute hérésie formelle, si on ne la rejette pas courageusement avant de paraître devant Dieu, entraine avec soi la perte certaine de la grâce et de l'eternité."

The Bishop recalls those whom he addresses from the false philosophy of the present to the philosophy of the past, and foresees the triumph of the latter. "Avant que le dix-neuvième siècle s'achève, la vieille philosophie scolastique aura repris sa place dans la juste admiration du monde. Il lui faudra pourtant bien du temps pour guérir les maux de tout genre, causes par son indigne rivale; et pendant de longues années encore, ce nom de *philosophie*, le plus grand de la langue humaine après celui de *religion*, sera suspect aux âmes qui se souviendront de la science impie et matérialiste de Locke, de Condillac ou d'Helvétius. L'heure actuelle est aux sciences naturelles: c'est maintenant l'instrument de combat contre l'Eglise et contre toute foi religieuse. Nous ne les redoutons pas." Further on the Bishop warns his readers that everything can be abused. Poetry is good, but in excess it may injure practical conduct. "Les mathématiques sont excellentes: et Bossuet les a louées 'comme étant ce qui sert le plus à la justesse du raisonnement'; mais si on s'accoutume exclusivement à leur méthode, rien de ce qui appar-

tient à l'ordre moral ne paraît plus pouvoir être démontré; et Fénelon a pu parler de *l'ensorcellement* et des attraits *diaboliques* de la géométrie."

The learned Bishop thus finally accentuates the claims of the Church: "Comme le définissait le Pape Léon X., au cinquième concile œcuménique de Latran, 'Le vrai ne peut pas être contraire à lui-même; par conséquent, toute assertion contraire à une verité de foi revelée est nécessairement et absolument fausse.' Il suit de là que, sans entrer dans l'examen scientifique de telle ou telle question de physiologie, mais par la seule certitude de nos dogmes, nous pouvons juger du sort de telle ou telle hypothèse, qui est une machine de guerre anti-chrétienne plutôt qu'une conquête sérieuse sur les secrets et les mystères de la nature. . . . C'est un dogme que l'homme a été formé et façonné des mains de Dieu. Donc il est faux, heretique, contraire à la dignité du Createur et offensant pour son chef-d'œuvre, de dire que l'homme constitue la *septième* espèce des singes . . . Heresie encore de dire que le genre humain n'est pas sorti d'un seul couple, et qu'on y peut compter jusqu'à *douze* races distinctes!"

The course of life upon earth, as far as Science can see, has been one of amelioration—a steady advance on the whole from the lower to the higher. The continued effort of animated nature is to improve its condition and raise itself to a loftier level. In man improvement and amelioration depend largely upon the growth of conscious knowledge, by which the errors of ignorance are continually moulted, and truth is organized. It is the advance of knowledge that has given a materialistic color to the philosophy of this age. Materialism is therefore not a

thing to be mourned over, but to be honestly considered—accepted if it be wholly true, rejected if it be wholly false, wisely sifted and turned to account if it embrace a mixture of truth and error. Of late years the study of the nervous system, and its relation to thought and feeling, have profoundly occupied inquiring minds. It is our duty not to shirk—it ought rather to be our privilege to accept—the established results of such inquiries, for here assuredly our ultimate weal depends upon our loyalty to the truth. Instructed as to the control which the nervous system exercises over man's moral and intellectual nature, we shall be better prepared, not only to mend their manifold defects, but also to strengthen and purify both. Is mind degraded by this recognition of its dependence? Assuredly not. Matter, on the contrary, is raised to the level it ought to occupy, and from which timid ignorance would remove it.

But the light is dawning, and it will become stronger as time goes on. Even the Brighton "Church Congress" affords evidence of this. From the manifold confusions of that assemblage my memory has rescued two items, which it would fain preserve: the recognition of a relation between Health and Religion, and the address of the Rev. Harry Jones. Out of the conflict of vanities his words emerge wholesome and strong, because undrugged by dogma, coming directly from the warm brain of one who knows what practical truth means, and who has faith in its vitality and inherent power of propagation. I wonder whether he is less effectual in his ministry than his more embroidered colleagues? It surely behooves our teachers to come to some definite understanding as to this question of health; to see how, by inattention to it, we are de-

frauded, negatively and positively: negatively, by the privation of that "sweetness and light" which is the natural concomitant of good health; positively, by the insertion into life of cynicism, ill-temper, and a thousand corroding anxieties which good health would dissipate. We fear and scorn "materialism." But he who knew all about it, and could apply his knowledge, might become the preacher of a new gospel. Not, however, through the ecstatic moments of the individual does such knowledge come, but through the revelations of science, in connection with the history of mankind.

Why should the Roman Catholic Church call gluttony a mortal sin? Why should fasting occupy a place in the disciplines of religion? What is the meaning of Luther's advice to the young clergyman who came to him, perplexed with the difficulties of predestination and election, if it be not that, in virtue of its action upon the brain, when wisely applied, there is moral and religious virtue even in a hydro-carbon? To use the old language, food and drink are creatures of God, and have therefore a spiritual value. Through our neglect of the monitions of a reasonable materialism we sin and suffer daily. I might here point to the train of deadly disorders over which science has given modern society such control—disclosing the lair of the material enemy, insuring his destruction, and thus preventing that moral squalor and hopelessness which habitually tread on the heels of epidemics in the case of the poor.

Rising to higher spheres, the visions of Swedenborg, and the ecstasy of Plotinus and Porphyry, are phases of that psychical condition, obviously connected with the nervous system and state of health, on which is based

the Vedic doctrine of the absorption of the individual into the universal soul. Plotinus taught the devout how to pass into a condition of ecstasy. Porphyry complains of having been only once united to God in eighty-six years, while his master Plotinus had been so united six times in sixty years.[1] A friend who knew Wordsworth informs me that the poet, in some of his moods, was accustomed to seize hold of an external object to assure himself of his own bodily existence. As states of consciousness such phenomena have an undisputed reality, and a substantial identity; but they are connected with the most heterogeneous objective conceptions. The subjective experiences are similar, because of the similarity of the underlying organizations.

But for those who wish to look beyond the practical facts, there will always remain ample room for speculation. Take the argument of the Lucretian introduced in the Belfast Address. As far as I am aware, not one of my assailants has attempted to answer it. Some of them, indeed, rejoice over the ability displayed by Bishop Butler in rolling back the difficulty on his opponent; and they even imagine that it is the Bishop's own argument that is there employed. But the raising of a new difficulty does not abolish—does not even lessen—the old one, and the argument of the Lucretian remains untouched by anything the Bishop has said or can say.

And here it may be permitted me to add a word to an important controversy now going on: and which turns on

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[1] I recommend to the reader's particular attention Dr. Draper's important work entitled, "History of the Conflict between Religion and Science" (Messrs. H. S. King & Co.).

the question: Do states of consciousness enter as links into the chain of antecedents and sequence, which give rise to bodily actions, and to other states of consciousness; or are they merely *by-products*, which are not essential to the physical processes going on in the brain? Speaking for myself, it is certain that I have no power of imagining states of consciousness, interposed between the molecules of the brain, and influencing the transference of motion among the molecules. The thought "eludes all mental presentation"; and hence the logic seems of iron strength which claims for the brain an automatic action, uninfluenced by states of consciousness. But it is, I believe, admitted by those who hold the automaton-theory, that states of consciousness are *produced* by the marshalling of the molecules of the brain: and this production of consciousness by molecular motion is to me quite as inconceivable on mechanical principles as the production of molecular motion by consciousness. If, therefore, I reject one result, I must reject both. I, however, reject neither, and thus stand in the presence of two Incomprehensibles, instead of one Incomprehensible. While accepting fearlessly the facts of materialism dwelt upon in these pages, I bow my head in the dust before that mystery of mind, which has hitherto defied its own penetrative power, and which may ultimately resolve itself into a demonstrable impossibility of self-penetration.

But the secret is an open one—the practical monitions are plain enough, which declare that on our dealings with matter depend our weal and woe, physical and moral. The state of mind which rebels against the recognition of the claims of "materialism" is not unknown to me. I can remember a time when I regarded my body as a weed, so

uch more highly did I prize the conscious strength and easure derived from moral and religious feeling—which, may add, was mine without the intervention of dogma. he error was not an ignoble one, but this did not save from the penalty attached to error. Saner knowledge ught me that the body is no weed, and that treated as ch it would infallibly avenge itself. Am I personally wered by this change of front? Not so. Give me their alth, and there is no spiritual experience of those ear- r years—no resolve of duty, or work of mercy, no work self-renouncement, no solemnity of thought, no joy in e life and aspects of nature—that would not still be ne; and this without the least reference or regard to y purely personal reward or punishment looming in the ture.

And now I have to utter a "farewell" free from bitter- ss to all my readers; thanking my friends for a sym- thy more steadfast, I would fain believe, if less noisy, an the antipathy of my foes; and commending to these passage from Bishop Butler, which they have either not ad or failed to lay to heart. "It seems," saith the shop, "that men would be strangely headstrong and f-willed, and disposed to exert themselves with an im- tuosity which would render society insupportable, and e living in it impracticable, were it not for some ac- ired moderation and self-government, some aptitude d readiness in restraining themselves, and concealing eir sense of things."

XI

THE REV. JAMES MARTINEAU AND THE BELFAST ADDRESS[1]

PRIOR to the publication of the Fifth Edition o
these "Fragments" my attention had been directe
by several estimable, and indeed eminent, person
to an essay by the Rev. James Martineau, as demandin
serious consideration at my hands. I tried to give th
essay the attention claimed for it, and published my view
of it as an Introduction to Part II. of the "Fragments.
I there referred, and here again refer with pleasure,
the accord subsisting between Mr. Martineau and myse
on certain points of biblical Cosmogony. "In so far
says he, "as Church belief is still committed to a giv
Cosmogony and natural history of man, it lies open
scientific refutation." And again: "It turns out th
with the sun and moon and stars, and in and on t
earth, before and after the appearance of our race, qu
other things have happened than those which the sacr
Cosmogony recites." Once more: "The whole history
the genesis of things Religion must surrender to t
Sciences." Finally, still more emphatically: "In the
vestigation of the genetic order of things, Theology is
intruder, and must stand aside." This expresses, only
words of fuller pith, the views which I ventured to en

[1] "Fortnightly Review."

ciate in Belfast. "The impregnable position of Science," I there say, "may be stated in a few words. We claim, and we shall wrest from Theology, the entire domain of Cosmological theory." Thus Theology, so far as it is represented by Mr. Martineau, and Science, so far as I understand it, are in absolute harmony here.

But Mr. Martineau would have just reason to complain of me if, by partial citation, I left my readers under the impression that the agreement between us is complete. At the opening of the eighty-ninth Session of the Manchester New College, London, on October 6, 1874, he, its principal, delivered an Address bearing the title "Religion as affected by Modern Materialism"; the references and general tone of which make evident the depth of its author's discontent with my previous deliverance at Belfast. I find it difficult to grapple with the exact grounds of this discontent. Indeed, logically considered, the impression left upon my mind by an essay of great æsthetic merit, containing many passages of exceeding beauty, and many sentiments which none but the pure in heart could utter as they are uttered here, is vague and unsatisfactory. The author appears at times so brave and liberal, at times so timid and captious, and at times, if I dare say it, so imperfectly informed, regarding the position he assails.

At the outset of his Address Mr. Martineau states with some distinctness his "sources of religious faith." They are two—"the scrutiny of Nature" and "the interpretation of Sacred Books." It would have been a theme worthy of his intelligence to have deduced from these two sources his religion as it stands. But not another word is said about the "Sacred Books." Having swept with the besom of Science various "books" contemptu-

ously away, he does not define the Sacred residue; much less give us the reasons why he deems them sacred.[1] His references to "Nature," on the other hand, are magnificent tirades against Nature, intended, apparently, to show the wholly abominable character of man's antecedents if the theory of evolution be true. Here also his mood lacks steadiness. While joyfully accepting, at one place, "the widening space, the deepening vistas of time, the detected marvels of physiological structure, and the rapid filling-in of the missing links in the chain of organic life," he falls, at another, into lamentation and mourning over the very theory which renders "organic life" "a chain." He claims the largest liberality for his sect, and avows its contempt for the dangers of possible discovery. But immediately afterward he damages the claim, and ruins all confidence in the avowal. He professes sympathy with modern Science, and almost in the same breath he treats, or certainly will be understood to treat, the Atomic Theory, and the doctrine of the Conservation of Energy, as if they were a kind of scientific thimble-riggery.

His ardor, moreover, renders him inaccurate; causing him to see discord between scientific men where nothing but harmony reigns. In his celebrated Address to the Congress of German Naturforscher, delivered at Leipzig, three years ago, Du Bois-Reymond speaks thus: "What conceivable connection subsists between definite movements of definite atoms in my brain, on the one hand,

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[1] Mr. Martineau's use of the term "sacred" is unintentionally misleading. In his later essays we are taught that he does not mean to restrict it to the Bible. He does not, however, mention the "books" beyond those of the Bible to which he would apply the term. 1879.

and, on the other hand, such primordial, indefinable, undeniable, facts as these: I feel pain or pleasure; I experience a sweet taste, or smell a rose, or hear an organ, or see something red. . . It is absolutely and forever inconceivable that a number of carbon, hydrogen, nitrogen, and oxygen atoms should be otherwise than indifferent as to their own position and motion, past, present, or future. It is utterly inconceivable how consciousness should result from their joint action."

This language, which was spoken in 1872, Mr. Martineau "freely" translates, and quotes against me. The act is due to misapprehension. Evidence is at hand to prove that I employed similar language twenty years ago. It is to be found in the "Saturday Review" for 1860; but a sufficient illustration of the agreement between my friend Du Bois-Reymond and myself is furnished by the discourse on "Scientific Materialism," delivered in 1868, then widely circulated, and reprinted here. The reader who compares the two discourses will see that the same line of thought is pursued in both, and that perfect agreement reigns between my friend and me. In the very Address he criticises, Mr. Martineau might have seen that precisely the same position is maintained. A quotation will prove this: "Thus far," I say, "our way is clear, but now comes my difficulty. Your atoms are individually without sensation, much more are they without intelligence. May I ask you, then, to try your hand upon this problem? Take your dead hydrogen atoms, your dead oxygen atoms, your dead carbon atoms, your dead nitrogen atoms, your dead phosphorus atoms, and all the other atoms, dead as grains of shot, of which the brain is formed. Imagine them separate and sensationless; ob-

serve them running together and forming all imaginable combinations. This, as a purely mechanical process, is *seeable* by the mind. But can you see, or dream, or in any way imagine, how out of that mechanical act, and from these individually dead atoms, sensation, thought, and emotion are to rise? Are you likely to extract Homer out of the rattling of dice, or the Differential Calculus out of the clash of billiard-balls? . . . I can follow a particle of musk until it reaches the olfactory nerve; I can follow the waves of sound until their tremors reach the water of the labyrinth, and set the otoliths and Corti's fibres in motion; I can also visualize the waves of ether as they cross the eye and hit the retina. Nay, more, I am able to pursue to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processes. What baffles and bewilders me is the notion that from these physical tremors things so utterly incongruous with them as sensation, thought, and emotion can be derived." It is only a complete misapprehension of our true relationship that could induce Mr. Martineau to represent Du Bois Reymond and myself as opposed to each other.

"The affluence of illustration," writes an able and sympathetic reviewer of this essay, in the New York "Tribune," "in which Mr. Martineau delights often impairs the distinctness of his statements by diverting the attention of the reader from the essential points of his discussion to the beauty of his imagery, and thus diminishes their power of conviction." To the beauties here referred to I bear willing testimony; but the reviewer is strictly just in his estimate of their effect upon my critic's logic. The "afflu-

ence of illustration," and the heat, and haze, and haste, generated by its reaction upon Mr. Martineau's own mind, often produce vagueness where precision is the one thing needful—poetic fervor where we require judicial calm; and practical unfairness where the strictest justice ought to be, and I willingly believe is meant to be, observed.

In one of his nobler passages Mr. Martineau tells us how the pupils of his college have been educated hitherto: "'They have been trained under the assumptions (1) that the Universe which includes us and folds us round is the life-dwelling of an Eternal Mind; (2) that the world of our abode is the scene of a moral government, incipient but not complete; and (3) that the upper zones of human affection, above the clouds of self and passion, take us into the sphere of a Divine Communion. Into this over-arching scene it is that growing thought and enthusiasm have expanded to catch their light and fire."

Alpine summits seem to kindle above us as we read these glowing words; we see their beauty and feel their life. At the close of one of the essays here printed,[1] I thus refer to the "Communion" which Mr. Martineau calls "'Divine": "'Two things,' said Immanuel Kant, 'fill me with awe—the starry heavens, and the sense of moral responsibility in man.' And in his hours of health and strength and sanity, when the stroke of action has ceased, and the pause of reflection has set in, the scientific investigator finds himself overshadowed by the same awe. Breaking contact with the hampering details of earth, it associates him with a Power which gives fulness and tone to his existence, but which he can neither analyze nor

[1] "Scientific Use of the Imagination."

comprehend." Though "knowledge" is here disavowed, the "feelings" of Mr. Martineau and myself are, I think, very much alike. He, nevertheless, censures me—almost denounces me—for referring Religion to the region of Emotion. Surely he is inconsistent here. The foregoing words refer to an inward hue or temperature, rather than to an external object of thought. When I attempt to give the Power which I see manifested in the Universe an objective form, personal or otherwise, it slips away from me, declining all intellectual manipulation. I dare not, save poetically, use the pronoun "He" regarding it; I dare not call it a "Mind"; I refuse to call it even a "Cause." Its mystery overshadows me; but it remains a mystery, while the objective frames which some of my neighbors try to make it fit seem to me to distort and desecrate it.

It is otherwise with Mr. Martineau, and hence his discontent. He professes to *know* where I only claim to *feel*. He could make his contention good against me if, by a process of verification, he would transform his assumptions into "objective knowledge." But he makes no attempt to do so. They remain assumptions from the beginning of his Address to its end. And yet he frequently uses the word "unverified," as if it were fatal to the position on which its incidence falls. "The scrutiny of Nature" is one of his sources of "religious faith": what logical foothold does that scrutiny furnish, on which any one of the foregoing three assumptions could be planted? Nature, according to his picturing, is base and cruel: what is the inference to be drawn regarding its Author? If Nature be "red in tooth and claw," who is responsible? On a Mindless nature Mr. Martineau pours the full torrent of his gorgeous invective; but could the "assumption" of

"an Eternal Mind"—even of a Beneficent Eternal Mind—render the world objectively a whit less mean and ugly than it is? Not an iota. It is man's feelings, and not external phenomena, that are influenced by the assumption. It adds not a ray of light nor a strain of music to the objective sum of things. It does not touch the phenomena of physical nature—storm, flood, or fire—nor diminish by a pang the bloody combats of the animal world. But it does add the glow of religious emotion to the human soul, as represented by Mr. Martineau. Beyond this I defy him to go; and yet he rashly—it might be said petulantly—kicks away the only philosophic foundation on which it is possible for him to build his religion.

He twits incidentally the modern scientific interpretation of nature because of its want of cheerfulness. "Let the new future," he says, "preach its own gospel, and devise, if it can, the means of making the tidings *glad*." This is a common argument: "If you only knew the comfort of belief!" My reply is that I choose the nobler part of Emerson, when, after various disenchantments, he exclaimed, "I covet *truth!*" The gladness of true heroism visits the heart of him who is really competent to say this. Besides, "gladness" is an emotion, and Mr. Martineau theoretically scorns the emotional. I am not, however, acquainted with a writer who draws more largely upon this source, while mistaking it for something objective. "To reach the Cause," he says, "there is no need to go into the past, as though, being missed here, He could be found there. But when once He has been apprehended by the proper organs of divine apprehension, the whole life of Humanity is recognized as the scene of His agency." That Mr. Martineau should have lived so long,

thought so much, and failed to recognize the entirely subjective character of this creed, is highly instructive. His "proper organs of divine apprehension"—given, we must assume, to Mr. Martineau and his pupils, but denied to many of the greatest intellects and noblest men in this and other ages—lie at the very core of his emotions.

In fact, it is when Mr. Martineau is most purely emotional that he scorns the emotions; it is when he is most purely subjective that he rejects subjectivity. He pays a just and liberal tribute to the character of John Stuart Mill. But in the light of Mill's philosophy, benevolence, honor, purity, having "shrunk into mere unaccredited subjective susceptibilities, have lost all support from Omniscient approval, and all presumable accordance with the reality of things." If Mr. Martineau had given them any inkling of the process by which he renders the "subjective susceptibilities" objective, or how he arrives at an objective ground of "Omniscient approval," gratitude from his pupils would have been his just meed. But, as it is, he leaves them lost in an iridescent cloud of words, after exciting a desire which he is incompetent to appease.

"We are," he says, in another place, "forever shaping our representations of invisible things into forms of definite opinion, and throwing them to the front, as if they were the photographic equivalent of our real faith. It is a delusion which affects us all. Yet somehow the essence of our religion never finds its way into these frames of theory: as we put them together it slips away, and, if we turn to pursue it, still retreats behind; ever ready to work with the will, to unbind and sweeten the affections, and bathe the life with reverence, but refusing to be seen, or to pass from a divine hue of thinking into a human pat-

because the man who utters it obviously brings it all out of the treasury of his own heart. But the "hue" and "pattern" here so finely spoken of, the former refusing to pass into the latter, are neither more nor less than that "emotion," on the one hand, and that "objective knowledge," on the other, which have drawn this suicidal fire from Mr. Martineau's battery.

I now come to one of the most serious portions of Mr. Martineau's pamphlet—serious far less on account of its "personal errors" than of its intrinsic gravity, though its author has thought fit to give it a witty and sarcastic tone. He analyzes and criticises "the materialist doctrine, which, in our time, is proclaimed with so much pomp, and resisted with so much passion. 'Matter is all I want,' says the physicist; 'give me its atoms alone, and I will explain the universe.'" It is thought, even by Mr. Martineau's intimate friends, that in this pamphlet he is answering me. I must therefore ask the reader to contrast the foregoing travesty with what I really do say regarding atoms: "I do not think that he [the materialist] is entitled to say that his molecular groupings and motions *explain* everything. In reality, they explain nothing. The utmost he can affirm is the association of two classes of phenomena, of whose real bond of union he is in absolute ignorance."[1] This is very different from saying, "Give me its atoms alone, and I will explain the universe." Mr. Martineau continues his dialogue with the physicist: "'Good,' he says; 'take as many atoms as you please. See that they have all that is requisite to Body

[1] Address on "Scientific Materialism."

[a metaphysical B], being homogeneous extended solids.' 'That is not enough,' his physicist replies; 'it might do for Democritus and the mathematicians, but I must have something more. The atoms must not only be in motion, and of various shapes, but also of as many kinds as there are chemical elements; for how could I ever get water if I had only hydrogen elements to work with?' 'So be it,' Mr. Martineau consents to answer, 'only this is a considerable enlargement of your specified datum [where, and by whom specified?]—in fact, a conversion of it into several; yet, even at the cost of its monism [put into it by Mr. Martineau], your scheme seems hardly to gain its end; for by what manipulation of your resources will you, for example, educe Consciousness?' "

This reads like pleasantry, but it deals with serious things. For the last seven years the question here proposed by Mr. Martineau, and my answer to it, have been accessible to all. The question, in my words, is briefly this: "A man can say, 'I feel, I think, I love,' but how does consciousness infuse itself into the problem?" And here is my answer: "The passage from the physics of the brain to the corresponding facts of consciousness is unthinkable. Granted that a definite thought and a definite molecular action in the brain occur simultaneously; we do not possess the intellectual organ, nor apparently any rudiment of the organ, which would enable us to pass, by a process of reasoning, from the one to the other. They appear together, but we do not know why. Were our minds and senses so expanded, strengthened, and illuminated, as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, all their groupings, all their electric discharges,

if such there be; and were we intimately acquainted with the corresponding states of thought and feeling, we should be as far as ever from the solution of the problem, 'How are these physical processes connected with the facts of consciousness?' The chasm between the two classes of phenomena would still remain intellectually impassable."[1]

Compare this with the answer which Mr. Martineau puts into the mouth of *his* physicist, and with which I am generally credited by Mr. Martineau's readers, both in England and America: "'It [the problem of consciousness] does not daunt me at all. Of course you understand that all along my atoms have been affected by gravitation and polarity; and now I have only to insist with Fechner on a difference among molecules: there are the *inorganic*, which can change only their *place*, like the particles in an undulation; and there are the *organic*, which can change *their order*, as in a globule that turns itself inside out. With an adequate number of these our problem will be manageable.' 'Likely enough,' we may say ['entirely unlikely,' say I], 'seeing how careful you are to provide for all emergencies; and if any hitch should occur in the next step, where you will have to pass from mere sentiency to thought and will, you can again look in upon your atoms, and fling among them a handful of Leibnitz's monads, to serve as souls in little, and be ready, in a latent form, with that Vorstellungs-fähigkeit which our picturesque interpreters of nature so much prize.'"

"But surely," continues Mr. Martineau, "you must observe that this 'matter' of yours alters its style with

[1] Bishop Butler's reply to the Lucretian in the "Belfast Address" is all in the same strain.

every change of service: starting as a beggar with scarce a rag of 'property' to cover its bones, it turns up as a prince when large undertakings are wanted. 'We must radically change our notions of matter,' says Professor Tyndall; and then, he ventures to believe, it will answer all demands, carrying 'the promise and potency of all terrestrial life.' If the measure of the required 'change in our notions' had been specified, the proposition would have had a real meaning, and been susceptible of a test. It is easy travelling through the stages of such a hypothesis; you deposit at your bank a round sum ere you start, and, drawing on it piecemeal at every pause, complete your grand tour without a debt."

The last paragraph of this argument is forcibly and ably stated. On it I am willing to try conclusions with Mr. Martineau. I may say, in passing, that I share his contempt for the picturesque interpretation of nature, if accuracy of vision be thereby impaired. But the term Vorstellungs-fähigkeit, as used by me, means the power of definite mental presentation, of attaching to words the corresponding objects of thought, and of seeing these in their proper relations, without the interior haze and soft penumbral borders which the theologian loves. To this mode of "interpreting nature" I shall to the best of my ability now adhere.

Neither of us, I trust, will be afraid or ashamed to begin at the alphabet of this question. Our first effort must be to understand each other, and this mutual understanding can only be insured by beginning low down. Physically speaking, however, we need not go below the sea level. Let us then travel in company to the Caribbean Sea, and halt upon the heated water. What is that sea,

and what is the sun that heats it? Answering for myself, I say that they are both *matter*. I fill a glass with the sea-water and expose it on the deck of the vessel; after some time the liquid has all disappeared, and left a solid residue of salt in the glass behind. We have mobility, invisibility—apparent annihilation. In virtue of

> The glad and secret aid
> The sun unto the ocean paid,

the water has taken to itself wings and flown off as vapor. From the whole surface of the Caribbean Sea such vapor is rising: and now we must follow it—not upon our legs, however, nor in a ship, nor even in a balloon, but by the mind's eye—in other words, by that power of Vorstellung which Mr. Martineau knows so well, and which he so justly scorns when it indulges in loose practices.

Compounding, then, the northward motion of the vapor with the earth's axial rotation, we track our fugitive through the higher atmospheric regions, obliquely across the Atlantic Ocean to Western Europe, and on to our familiar Alps. Here another wonderful metamorphosis occurs. Floating on the cold calm air, and in presence of the cold firmament, the vapor condenses, not only to particles of water, but to particles of crystalline water. These coalesce to stars of snow, which fall upon the mountains in forms so exquisite that, when first seen, they never fail to excite rapture. As to beauty, indeed, they put the work of the lapidary to shame, while as to accuracy they render concrete the abstractions of the geometer. Are these crystals "matter"? Without presuming to dogmatize, I answer for myself in the affirmative.

Still, a *formative power* has obviously here come into

play which did not manifest itself in either the liquid or the vapor. The question now is, Was not the power "potential" in both of them, requiring only the proper conditions of temperature to bring it into action? Again I answer for myself in the affirmative. I am, however, quite willing to discuss with Mr. Martineau the alternative hypothesis, that an imponderable formative soul unites itself with the substance after its escape from the liquid state. If he should espouse this hypothesis, then I should demand of him an immediate exercise of that Vorstellungsfähigkeit, with which, in my efforts to think clearly, I can never dispense. I should ask, At what moment did the soul come in? Did it enter at once or by degrees; perfect from the first, or growing and perfecting itself contemporaneously with its own handiwork? I should also ask whether it is localized or diffused? Does it move about as a lonely builder, putting the bits of solid water in their places as soon as the proper temperature has set in? or is it distributed through the entire mass of the crystal? If the latter, then the soul has the shape of the crystal; but if the former, then I should inquire after its shape. Has it legs or arms? If not, I would ask it to be made clear to me how a thing without these appliances can act so perfectly the part of a builder? (I insist on definition, and ask unusual questions, if haply I might thereby banish unmeaning words.) What were the condition and residence of the soul before it joined the crystal? What becomes of it when the crystal is dissolved? Why should a particular temperature be needed before it can exercise its vocation? Finally, is the problem before us in any way simplified by the assumption of its existence? I think it probable that, after a full discussion of the ques-

tion, Mr. Martineau would agree with me in ascribing the building power displayed in the crystal to the bits of water themselves. At all events, I should count upon his sympathy so far as to believe that he would consider any one unmannerly who would denounce me for rejecting this notion of a separate soul, and for holding the snow-crystal to be "matter."

But then what an astonishing addition is here made to the powers of matter! Who would have dreamed, without actually seeing its work, that such a power was locked up in a drop of water? All that we needed to make the action of the *liquid* intelligible was the assumption of Mr. Martineau's "homogeneous extended atomic solids," smoothly gliding over one another. But had we supposed the water to be nothing more than this, we should have ignorantly defrauded it of an intrinsic architectural power, which the art of man, even when pushed to its utmost degree of refinement, is incompetent to imitate. I would invite Mr. Martineau to consider how inappropriate his figure of a fictitious bank deposit becomes under these circumstances. The "account current" of matter receives nothing at my hands which could be honestly kept back from it. If, then, "Democritus and the mathematicians" so defined matter as to exclude the powers here proved to belong to it, they were clearly wrong, and Mr. Martineau, instead of twitting me with my departure from them, ought rather to applaud me for correcting them.[1]

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[1] Definition implies previous examination of the object defined, and is open to correction or modification as knowledge of the object increases. F
creased knowledge has radically changed our conceptions of the
ether, converting its vibrations from longitudinal into transverse.
also Mr. Martineau's conceptions of matter are doomed to under

The reader of my small contributions to the literature which deals with the overlapping margins of Science and Theology, will have noticed how frequently I quote Mr. Emerson. I do so mainly because in him we have a poet and a profoundly religious man, who is really and entirely undaunted by the discoveries of Science, past, present, or prospective. In his case Poetry, with the joy of a bacchanal, takes her graver brother Science by the hand, and cheers him with immortal laughter. By Emerson scientific conceptions are continually transmuted into the finer forms and warmer hues of an ideal world. Our present theme is touched upon in the lines —

> The journeying atoms, primordial wholes
> Firmly draw, firmly drive by their animate poles.

As regards veracity and insight these few words outweigh, in my estimation, all the formal learning expended by Mr. Martineau in those disquisitions on Force, where he treats the physicist as a conjurer, and speaks so wittily of atomic polarity. In fact, without this notion of polarity—this "drawing" and "driving"—this attraction and repulsion, we stand as stupidly dumb before the phenomena of Crystallization as a Bushman before the phenomena of the Solar System. The genesis and growth of the notion I have endeavored to make clear in my third Lecture on Light, and in the article on "Matter and Force" published in this volume.

Our further course is here foreshadowed. A Sunday or two ago I stood under an oak planted by Sir John Moore, the hero of Corunna. On the ground near the tree little oaklets were successfully fighting for life with the surrounding vegetation. The acorns had dropped into

the friendly soil, and this was the result of their interaction. What is the acorn? what the earth? and what the sun, without whose heat and light the tree could not become a tree, however rich the soil, and however healthy the seed? I answer for myself as before—all "matter." And the heat and light which here play so potent a part are acknowledged to be motions of matter. By taking something much lower down in the vegetable kingdom than the oak, we might approach much more nearly to the case of crystallization already discussed; but this is not now necessary.

If, instead of conceding the sufficiency of matter here, Mr. Martineau should fly to the hypothesis of a vegetative soul, all the questions before asked in relation to the snow-star become pertinent. I would invite him to go over them one by one, and consider what replies he will make to them. He may retort by asking me, "Who infused the principle of life into the tree?" I say, in answer, that our present question is not this, but another—not who made the tree, but what *is* it? Is there anything besides matter in the tree? If so, what, and where? Mr. Martineau may have begun by this time to discern that it is not "picturesqueness," but cold precision, that my Vorstellungs-fähigkeit demands. How, I would ask, is this vegetative soul to be presented to the mind? where did it flourish before the tree grew? and what will become of it when the tree is sawn into planks, or consumed in fire?

Possibly Mr. Martineau may consider the assumption of this soul to be as untenable and as useless as I do. But then if the power to build a tree be conceded to pure matter, what an amazing expansion of our notions of the "potency of matter" is implied in the concession! Think of

the acorn, of the earth, and of the solar light and heat—was ever such necromancy dreamed of as the production of that massive trunk, those swaying boughs and whispering leaves, from the interaction of these three factors? In this interaction, moreover, consists what we call *life*. It will be seen that I am not in the least insensible to the wonder of the tree; nay, I should not be surprised if, in the presence of this wonder, I feel more perplexed and overwhelmed than Mr. Martineau himself.

Consider it for a moment. There is an experiment, first made by Wheatstone, where the music of a piano is transferred from its sound-board, through a thin wooden rod, across several silent rooms in succession, and poured out at a distance from the instrument. The strings of the piano vibrate, not singly, but ten at a time. Every string subdivides, yielding not one note, but a dozen. All these vibrations and subvibrations are crowded together into a bit of deal not more than a quarter of a square inch in section. Yet no note is lost. Each vibration asserts its individual rights; and all are, at last, shaken forth into the air by a second sound-board, against which the distant end of the rod presses. Thought ends in amazement when it seeks to realize the motions of that rod as the music flows through it. I turn to my tree and observe its roots, its trunk, its branches, and its leaves. As the rod conveys the music, and yields it up to the distant air, so does the trunk convey the matter and the motion—the shocks and pulses and other vital actions—which eventually emerge in the umbrageous foliage of the tree. I went some time ago through the greenhouse of a friend. He had ferns from Ceylon, the branches of which were in some cases not much thicker than an ordinary pin—hard,

smooth, and cylindrical—often leafless for a foot or more. But at the end of every one of them the unsightly twig unlocked the exuberant beauty hidden within it, and broke forth into a mass of fronds, almost large enough to fill the arms. We stand here upon a higher level of the wonderful: we are conscious of a music subtler than that of the piano, passing unheard through these tiny boughs, and issuing in what Mr. Martineau would opulently call the "clustered magnificence" of the leaves. Does it lessen my amazement to know that every cluster, and every leaf—their form and texture—lie, like the music in the rod, in the molecular structure of these apparently insignificant stems? Not so. Mr. Martineau weeps for "the beauty of the flower fading into a necessity." I care not whether it comes to me through necessity or through freedom, my delight in it is all the same. I see what he sees with a wonder superadded. To me, as to him, not even Solomon in all his glory was arrayed like one of these.

I have spoken above as if the assumption of a soul would save Mr. Martineau from the inconsistency of crediting pure matter with the astonishing building power displayed in crystals and trees. This, however, would not be the necessary result; for it would remain to be proved that the soul assumed is not itself matter. When a boy I learned from Dr. Watts that the souls of conscious brutes are mere matter. And the man who would claim for matter the human soul itself, would find himself in very orthodox company. "All that is created," says Fauste, a famous French bishop of the fifth century, "is matter. The soul occupies a place; it is enclosed in a body; it quits the body at death, and returns to it at the resurrection, as in the case of Lazarus; the distinction between

Hell and Heaven, between eternal pleasures and eternal pains, proves that, even after death, souls occupy a place and are corporeal. God only is incorporeal." Tertullian, moreover, was quite a physicist in the definiteness of his conceptions regarding the soul. "The materiality of the soul," he says, "is evident from the evangelists. A human soul is there expressly pictured as suffering in hell; it is placed in the middle of a flame, its tongue feels a cruel agony, and it implores a drop of water at the hands of a happier soul. *Wanting materiality*," adds Tertullian, "*all this would be without meaning*."[1]

I have glanced at inorganic nature—at the sea, and the sun, and the vapor, and the snow-flake, and at organic nature as represented by the fern and the oak. That same sun which warmed the water and liberated the vapor exerts a subtler power on the nutriment of the tree. It takes hold of matter wholly unfit for the purposes of nutrition, separates its nutritive from its non-nutritive portions, gives the former to the vegetable, and carries the others away. Planted in the earth, bathed by the air, and tended by the sun, the tree is traversed by its sap, the cells are formed, the woody fibre is spun, and the whole is woven to a texture wonderful even to the naked eye, but a million-fold more so to microscopic vis-

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[1] The foregoing extracts, which M. Alglave recently brought to light for the benefit of the Bishop of Orleans, are taken from the sixth Lecture of the "Cours d'Histoire Moderne" of that most orthodox of statesmen, M. Guizot. "I could multiply," continues M. Guizot, "these citations to infinity, and they prove that in the first centuries of our era the materiality of the soul was an opinion not only permitted, but dominant." Dr. Moriarty, and the synod which he recently addressed, obviously forget their own antecedents. Their boasted succession from the early Church renders them the direct offspring of a "materialism" more "brutal" than any ever enunciated by me.

. Does consciousness mix in any way with these proc-
es? No man can tell. Our only ground for a negative
clusion is the absence of those outward manifestations
m which feeling is usually inferred. But even these
not entirely absent. In the greenhouses of Kew we
y see that a leaf can close, in response to a proper
nulus, as promptly as the human fingers themselves;
while there Dr. Hooker will tell us of the wondrous
catching and fly-devouring power of the Dionæa. No
n can say that the feelings of the animal are not repre-
ted by a drowsier consciousness in the vegetable world.
all events, no line has ever been drawn between the
scious and the unconscious; for the vegetable shades
the animal by such fine gradations that it is impos-
e to say where the one ends and the other begins.

In all such inquiries we are necessarily limited by our
n powers: we observe what our senses, armed with the
s furnished by Science, enable us to observe; nothing
re. The evidences as to consciousness in the vegetable
ld depend wholly upon our capacity to observe and
gh them. Alter the capacity, and the evidence would
r too. Would that which to us is a total absence of
manifestation of consciousness be the same to a being
h our capacities indefinitely multiplied? To such a
ng I can imagine not only the vegetable, but the min-
world, responsive to the proper irritants, the response
ering only in degree from those exaggerated manifesta-
ns, which, in virtue of their magnitude, appeal to our
k powers of observation.

Our conclusion, however, must be based, not on pow-
that we imagine, but upon those that we possess.
at do they reveal? As the earth and atmosphere of-

fer themselves as the nutriment of the vegetable world, so does the latter, which contains no constituent not found in inorganic nature, offer itself to the animal world. Mixed with certain inorganic substances—water, for example—the vegetable constitutes, in the long run, the sole sustenance of the animal. Animals may be divided into two classes, the first of which can utilize the vegetable world immediately, having chemical forces strong enough to cope with its most refractory parts; the second class use the vegetable world mediately; that is to say, after its finer portions have been extracted and stored up by the first. But in neither class have we an atom newly created. The animal world is, so to say, a distillation through the vegetable world from inorganic nature.

From this point of view all three worlds would constitute a unity, in which I picture life as immanent everywhere. Nor am I anxious to shut out the idea that the life here spoken of may be but a subordinate part and function of a Higher Life, as the living, moving blood is subordinate to the living man. I resist no such idea as long as it is not dogmatically imposed. Left for the human mind freely to operate upon, the idea has ethical vitality; but, stiffened into a dogma, the inner force disappears, and the outward yoke of a usurping hierarchy takes its place.

The problem before us is, at all events, capable of definite statement. We have on the one hand strong grounds for concluding that the earth was once a molten mass. We now find it not only swathed by an atmosphere, and covered by a sea, but also crowded with living things. The question is, How were they introduced? Certainty may be as unattainable here as Bishop Butler

held it to be in matters of religion; but in the contemplation of probabilities the thoughtful mind is forced to take a side. The conclusion of Science, which recognizes unbroken causal connection between the past and the present, would undoubtedly be that the molten earth contained within it elements of life, which grouped themselves into their present forms as the planet cooled. The difficulty and reluctance encountered by this conception arise solely from the fact that the theologic conception obtained a prior footing in the human mind. Did the latter depend upon reasoning alone, it could not hold its ground for an hour against its rival. But it is warmed into life and strength by associated hopes and fears—and not only by these, which are more or less mean, but by that loftiness of thought and feeling which lifts its possessor above the atmosphere of self, and which the theologic idea, in its nobler forms, has engendered in noble minds.

Were not man's origin implicated, we should accept without a murmur the derivation of animal and vegetable life from what we call inorganic nature. The conclusion of pure intellect points this way and no other. But the purity is troubled by our interests in this life, and by our hopes and fears regarding the life to come. Reason is traversed by the emotions, anger rising in the weaker heads to the height of suggesting that the suppression of the inquirer by the arm of the law would be an act agreeable to God, and serviceable to man. But this foolishness is more than neutralized by the sympathy of the wise; and in England at least, so long as the courtesy which befits an earnest theme is adhered to, such sympathy is ever ready for an honest man. None of us here need shrink from saying all that he has a right to say. We

ought, however, to remember that it is not only a band of Jesuits, weaving their schemes of intellectual slavery, under the innocent guise "of education," that we are opposing. Our foes are to some extent of our own household, including not only the ignorant and the passionate, but a minority of minds of high calibre and culture, lovers of freedom moreover, who, though its objective hull be riddled by logic, still find the ethic life of their religion unimpaired. But while such considerations ought to influence the *form* of our argument, and prevent it from ever slipping out of the region of courtesy into that of scorn or abuse, its *substance*, I think, ought to be maintained and presented in unmitigated strength.

In the year 1855 the chair of philosophy in the University of Munich happened to be filled by a Catholic priest of great critical penetration, great learning, and great courage, who had borne the brunt of battle long before Döllinger. His Jesuit colleagues, he knew, inculcated the belief that every human soul is sent into the world from God by a separate and supernatural act of creation. In a work entitled the "Origin of the Human Soul," Professor Frohschammer, the philosopher here alluded to, was hardy enough to question this doctrine, and to affirm that man, body and soul, comes from his parents, the act of creation being, therefore, mediate and secondary only. The Jesuits keep a sharp lookout on all temerities of this kind; and their organ, the "Civiltà Cattolica," immediately pounced upon Frohschammer. His book was branded as "pestilent," placed in the Index, and stamped with the condemnation of the Church.[1] The

[1] King Maximilian II. brought Liebig to Munich, he helped Helmholtz in his researches, and loved to liberate and foster science. But through his liberal

Jesuit notion does not err on the score of indefiniteness. According to it, the Power whom Goethe does not dare to name, and whom Gassendi and Clerk Maxwell present to us under the guise of a "Manufacturer" of atoms, turns out annually, for England and Wales alone, a quarter of a million of new souls. Taken in connection with the dictum of Mr. Carlyle, that this annual increment to our population are "mostly fools," but little profit to the human heart seems derivable from this mode of regarding the Divine operations.

But if the Jesuit notion be rejected, what are we to accept? Physiologists say that every human being comes from an egg not more than the $\frac{1}{120}$th of an inch in diameter. Is this egg matter? I hold it to be so, as much as the seed of a fern or of an oak. Nine months go to the making of it into a man. Are the additions made during this period of gestation drawn from matter? I think so undoubtedly. If there be anything besides matter in the egg, or in the infant subsequently slumbering in the womb, what is it? The questions already asked with reference to the stars of snow may be here repeated. Mr. Martineau will complain that I am disenchanting the babe of its wonder; but is this the case? I figure it growing in the womb, woven by a something not itself, without conscious participation on the part of either father or mother, and appearing in due time a living miracle, with all its organs and all their implications. Consider the work accomplished during these nine months in forming

concession of power to the Jesuits in the schools, he did far more damage to the intellectual freedom of his country than his superstitious predecessor Ludwig I. Priding himself on being a German Prince, Ludwig would not tolerate the interference of the Roman party with the political affairs of Bavaria.

the eye alone—with its lens, and its humors, and its miraculous retina behind. Consider the ear with its tympanum, cochlea, and Corti's organ—an instrument of three thousand strings, built adjacent to the brain, and employed by it to sift, separate, and interpret, antecedent to all consciousness, the sonorous tremors of the external world. All this has been accomplished, not only without man's contrivance, but without his knowledge, the secret of his own organization having been withheld from him since his birth in the immeasurable past, until these latter days. Matter I define as that mysterious thing by which all this is accomplished. How it came to have this power is a question on which I never ventured an opinion. If, then, Matter starts as "a beggar," it is, in my view, because the Jacobs of theology have deprived it of its birthright. Mr. Martineau need fear no disenchantment. Theories of evolution go but a short way toward the explanation of this mystery; the Ages, let us hope, will at length give us a Poet competent to deal with it aright.

There are men, and they include among them some of the best of the race of man, upon whose minds this mystery falls without producing either warmth or color. The "dry light" of the intellect suffices for them, and they live their noble lives untouched by a desire to give the mystery shape or expression. There are, on the other hand, men whose minds are warmed and colored by its presence, and who, under its stimulus, attain to moral heights which have never been overtopped. Different spiritual climates are necessary for the healthy existence of these two classes of men; and different climates must be accorded them. The history of humanity, however, proves the experience of the second class to illustrate the

most pervading need. The world will have religion of some kind, even though it should fly for it to the intellectual whoredom of "spiritualism." What is really wanted is the lifting power of an ideal element in human life. But the free play of this power must be preceded by its release from the practical materialism of the present, as well as from the torn swaddling bands of the past. It is now in danger of being stupefied by the one, or strangled by the other. I look, however, forward to a time when the strength, insight, and elevation which now visit us in mere hints and glimpses, during moments "of clearness and vigor," shall be the stable and permanent possession of purer and mightier minds than ours—purer and mightier, partly because of their deeper knowledge of matter and their more faithful conformity to its laws.

XII

FERMENTATION, AND ITS BEARINGS ON SURGERY AND MEDICINE[1]

ONE of the most remarkable characteristics of the age in which we live, is its desire and tendency to connect itself organically with preceding ages—to ascertain how the state of things that now is came to be what it is. And the more earnestly and profoundly this problem is studied, the more clearly comes into view the vast and varied debt which the world of to-day owes to that fore-world, in which man by skill, valor, and well-directed strength first replenished and subdued the earth. Our prehistoric fathers may have been savages, but they were clever and observant ones. They founded agriculture by the discovery and development of seeds whose origin is now unknown. They tamed and harnessed their animal antagonists, and sent them down to us as ministers, instead of rivals in the fight for life. Later on, when the claims of luxury added themselves to those of necessity, we find the same spirit of invention at work. We have no historic account of the first brewer, but we glean from history that his art was practiced, and its produce relished, more than two thousand years ago. Theophrastus, who was born nearly four hundred years

[1] A Discourse delivered before the Glasgow Science Lectures Association, October 19, 1876.

before Christ, described beer as *the wine of barley.* It is extremely difficult to preserve beer in a hot country, still, Egypt was the land in which it was first brewed, the desire of man to quench his thirst with this exhilarating beverage overcoming all the obstacles which a hot climate threw in the way of its manufacture.

Our remote ancestors had also learned by experience that wine maketh glad the heart of man. Noah, we are informed, planted a vineyard, drank of the wine, and experienced the consequences. But, though wine and beer possess so old a history, a very few years ago no man knew the secret of their formation. Indeed, it might be said that until the present year no thorough and scientific account was ever given of the agencies which come into play in the manufacture of beer, of the conditions necessary to its health, and of the maladies and vicissitudes to which it is subject. Hitherto the art and practice of the brewer have resembled those of the physician, both being founded on empirical observation. By this is meant the observation of facts, apart from the principles which explain them, and which give the mind an intelligent mastery over them. The brewer learned from long experience the conditions, not the reasons, of success. But he had to contend, and has still to contend, against unexplained perplexities. Over and over again his care has been rendered nugatory; his beer has fallen into acidity or rottenness, and disastrous losses have been sustained, of which he has been unable to assign the cause. It is the hidden enemies against which the physician and the brewer have hitherto contended, that recent researches are dragging into the light of day, thus preparing the way for their final extermination.

Let us glance for a moment at the outward and visible signs of fermentation. A few weeks ago I paid a visit to a private still in a Swiss chalet; and this is what I saw. In the peasant's bedroom was a cask with a very large bunghole carefully closed. The cask contained cherries which had lain in it for fourteen days. It was not entirely filled with the fruit, an air-space being left above the cherries when they were put in. I had the bung removed, and a small lamp dipped into this space. Its flame was instantly extinguished. The oxygen of the air had entirely disappeared, its place being taken by carbonic acid gas.[1] I tasted the cherries: they were very sour, though when put into the cask they were sweet. The cherries and the liquid associated with them were then placed in a copper boiler, to which a copper head was closely fitted. From the head proceeded a copper tube which passed straight through a vessel of cold water, and issued at the other side. Under the open end of the tube was placed a bottle to receive the spirit distilled. The flame of small wood-splinters being applied to the boiler, after a time vapor rose into the head, passed through the tube, was condensed by the cold of the water, and fell in a liquid fillet into the bottle. On being tasted, it proved to be that fiery and intoxicating spirit known in commerce as Kirsch or Kirschwasser.

The cherries, it should be remembered, were left to themselves, no ferment of any kind being added to them. In this respect what has been said of the cherry applies also to the grape. At the vintage the fruit of the vine is

[1] The gas which is exhaled from the lungs after the oxygen of the air has done its duty in purifying the blood, the same also which effervesces from soda-water and champagne.

placed in proper vessels, and abandoned to its own action. It ferments, producing carbonic acid; its sweetness disappears, and at the end of a certain time the unintoxicating grape-juice is converted into intoxicating wine. Here, as in the case of the cherries, the fermentation is spontaneous —in what sense spontaneous will appear more clearly by and by.

It is needless for me to tell a Glasgow audience that the beer-brewer does not set to work in this way. In the first place the brewer deals not with the juice of fruits, but with the juice of barley. The barley having been steeped for a sufficient time in water, it is drained and subjected to a temperature sufficient to cause the moist grain to germinate; after which it is completely dried upon a kiln. It then receives the name of *malt*. The malt is crisp to the teeth, and decidedly sweeter to the taste than the original barley. It is ground, mashed up in warm water, then boiled with hops until all the soluble portions have been extracted; the infusion thus produced being called the *wort*. This is drawn off, and cooled as rapidly as possible; then, instead of abandoning the infusion, as the wine-maker does, to its own action, the brewer mixes yeast with his wort, and places it in vessels each with only one aperture open to the air. Soon after the addition of the yeast, a brownish froth, which is really new yeast, issues from the aperture, and falls like a cataract into troughs prepared to receive it. This frothing and foaming of the wort is a proof that the fermentation is active.

Whence comes the yeast which issues so copiously from the fermenting tub? What is this yeast, and how did the brewer become possessed of it? Examine its

quantity before and after fermentation. The brewer introduces, say, 10 cwts. of yeast, he collects 40, or it may be 50, cwts. The yeast has, therefore, augmented from four to five fold during the fermentation. Shall we conclude that this additional yeast has been spontaneously generated by the wort? Are we not rather reminded of that seed which fell into good ground, and brought forth fruit, some thirty fold, some sixty fold, some a hundred-fold? On examination, this notion of organic growth turns out to be more than a mere surmise. In the year 1680, when the microscope was still in its infancy, Leeuwenhook turned the instrument upon this substance, and found it composed of minute globules suspended in a liquid. Thus knowledge rested until 1835, when Cagniard de la Tour in France, and Schwann in Germany, independently, but animated by a common thought, turned microscopes of improved definition and heightened powers upon yeast, and found it budding and sprouting before their eyes. The augmentation of the yeast alluded to above was thus proved to arise from the growth of a minute plant now called *Torula* (or *Saccharomyces*) *Cerevisiæ*. Spontaneous generation is therefore out of the question. The brewer deliberately sows the yeast plant, which grows and multiplies in the wort as its proper soil. This discovery marks an epoch in the history of fermentation.

But where did the brewer find his yeast? The reply to this question is similar to that which must be given if it were asked where the brewer found his barley. He has received the seeds of both of them from preceding generations. Could we connect without solution of continuity the present with the past, we should probably be able

to trace back the yeast employed by my friend Sir Fowell Buxton to-day to that employed by some Egyptian brewer two thousand years ago. But you may urge that there must have been a time when the first yeast-cell was generated. Granted—exactly as there was a time when the first barley-corn was generated. Let not the delusion lay hold of you that a living thing is easily generated because it is small. Both the yeast-plant and the barley-plant lose themselves in the dim twilight of antiquity, and in this our day there is no more proof of the spontaneous generation of the one than there is of the spontaneous generation of the other.

I stated a moment ago that the fermentation of grape-juice was spontaneous; but I was careful to add, "in what sense spontaneous will appear more clearly by and by." Now this is the sense meant. The wine-maker does not, like the brewer and distiller, deliberately introduce either yeast, or any equivalent of yeast, into his vats; he does not consciously sow in them any plant, or the germ of any plant; indeed, he has been hitherto in ignorance whether plants or germs of any kind have had anything to do with his operations. Still, when the fermented grape-juice is examined, the living *Torula* concerned in alcoholic fermentation never fails to make its appearance. How is this? If no living germ has been introduced into the wine-vat, whence comes the life so invariably developed there?

You may be disposed to reply, with Turpin and others, that, in virtue of its own inherent powers, the grape-juice, when brought into contact with the vivifying atmospheric oxygen, runs spontaneously and of its own accord into these low forms of life. I have not the slightest ob-

jection to this explanation, provided proper evidence can be adduced in support of it. But the evidence adduced in its favor, as far as I am acquainted with it, snaps asunder under the strain of scientific criticism. It is, as far as I can see, the evidence of men, who, however keen and clever as *observers*, are not rigidly trained *experimenters*. These alone are aware of the precautions necessary in investigations of this delicate kind. In reference, then, to the life of the wine-vat, what is the decision of experiment when carried out by competent men? Let a quantity of the clear, filtered "must" of the grape be so boiled as to destroy such germs as it may have contracted from the air or otherwise. In contact with germless air the uncontaminated must never ferments. All the materials for spontaneous generation are there, but so long as there is no seed sown there is no life developed, and no sign of that fermentation which is the concomitant of life. Nor need you resort to a boiled liquid. The grape is sealed by its own skin against contamination from without. By an ingenious device, Pasteur has extracted from the interior of the grape its pure juice, and proved that in contact with pure air it never acquires the power to ferment itself, nor to produce fermentation in other liquids.[1] It is not, therefore, in the interior of the grape that the origin of the life observed in the vat is to be sought.

What then is its true origin? This is Pasteur's answer, which his well-proved accuracy renders worthy of all confidence. At the time of the vintage microscopic particles are observed adherent, both to the outer surface

[1] The liquids of the healthy animal body are also sealed from external contamination. Pure blood, for example, drawn with due precautions from the veins, will never ferment or putrefy in contact with pure air.

of the grape and of the twigs which support the grape. Brush these particles into a capsule of pure water. It is rendered turbid by the dust. Examined by a microscope, some of these minute particles are seen to present the appearance of organized cells. Instead of receiving them in water, let them be brushed into the pure inert juice of the grape. Forty-eight hours after this is done, our familiar *Torula* is observed budding and sprouting, the growth of the plant being accompanied by all the other signs of active fermentation. What is the inference to be drawn from this experiment? Obviously that the particles adherent to the external surface of the grape include the germs of that life which, after they have been sown in the juice, appears in such profusion. Wine is sometimes objected to on the ground that fermentation is "artificial"; but we notice here the responsibility of nature. The ferment of the grape clings like a parasite to the surface of the grape; and the art of the wine-maker from time immemorial has consisted in bringing—and it may be added, ignorantly bringing—two things thus closely associated by nature into actual contact with each other. For thousands of years, what has been done consciously by the brewer has been done unconsciously by the wine-grower. The one has sown his leaven just as much as the other.

Nor is it necessary to impregnate the beer-wort with yeast to provoke fermentation. Abandoned to the contact of our common air, it sooner or later ferments; but the chances are that the produce of that fermentation, instead of being agreeable, would be disgusting to the taste. By a rare accident we might get the true alcoholic fermentation, but the odds against obtaining it would be enormous. Pure air acting upon a lifeless liquid will

never provoke fermentation; but our ordinary air is the vehicle of numberless germs which act as ferments when they fall into appropriate infusions. Some of them produce acidity, some putrefaction. The germs of our yeast-plant are also in the air; but so sparingly distributed that an infusion like beer-wort, exposed to the air, is almost sure to be taken possession of by foreign organisms. In fact, the maladies of beer are wholly due to the admixture of these objectionable ferments, whose forms and modes of nutrition differ materially from those of the true leaven.

Working in an atmosphere charged with the germs of these organisms, you can understand how easy it is to fall into error in studying the action of any one of them. Indeed it is only the most accomplished experimenter, who, moreover, avails himself of every means of checking his conclusions, that can walk without tripping through this land of pitfalls. Such a man the French chemist Pasteur has hitherto proved himself to be. He has taught us how to separate the commingled ferments of our air, and to study their pure individual action. Guided by him, let us fix our attention more particularly upon the growth and action of the true yeast-plant under different conditions. Let it be sown in a fermentable liquid, which is supplied with plenty of pure air. The plant will flourish in the aërated infusion, and produce large quantities of carbonic acid gas—a compound, as you know, of carbon and oxygen. The oxygen thus consumed by the plant is the free oxygen of the air, which we suppose to be abundantly supplied to the liquid. The action is so far similar to the respiration of animals, which inspire oxygen and expire carbonic acid. If we examine the liquid even when the vigor of the plant has reached its maximum, we hardly

find in it a trace of alcohol. The yeast *has* grown and flourished, but it has almost ceased to act as a ferment. And could every individual yeast-cell seize, without any impediment, free oxygen from the surrounding liquid, it is certain that it would cease to act as a ferment altogether.

What, then, are the conditions under which the yeast-plant must be placed so that it may display its characteristic quality? Reflection on the facts already referred to suggests a reply, and rigid experiment confirms the suggestion. Consider the Alpine cherries in their closed vessel. Consider the beer in its barrel, with a single small aperture open to the air, through which it is observed not to imbibe oxygen, but to pour forth carbonic acid. Whence come the volumes of oxygen necessary to the production of this latter gas? The small quantity of atmospheric air dissolved in the wort and overlying it would be totally incompetent to supply the necessary oxygen. In no other way can the yeast-plant obtain the gas necessary for its respiration than by wrenching it from surrounding substances in which the oxygen exists, not free, but in a state of combination. It decomposes the sugar of the solution in which it grows, produces heat, breathes forth carbonic acid gas, and one of the liquid products of the decomposition is our familiar alcohol. The act of fermentation, then, is a result of the effort of the little plant to maintain its respiration by means of *combined* oxygen, when its supply of free oxygen is cut off. As defined by Pasteur, fermentation is *life without air.*

But here the knowledge of that thorough investigator comes to our aid to warn us against errors which have been committed over and over again. It is not all yeast-cells that can thus live without air and provoke fermentation.

bonic acid given out. But the process did not end here. After the oxygen had vanished, carbonic acid, in considerable quantities, continued to be exhaled by the fruits, which at the same time lost a portion of their sugar, becoming more acid to the taste, though the absolute quantity of acid was not augmented. This was an observation of capital importance, and Bérard had the sagacity to remark that the process might be regarded as a kind of fermentation.

Thus the living cells of fruits can absorb oxygen and breathe out carbonic acid, exactly like the living cells of the leaven of beer. Supposing the access of oxygen suddenly cut off, will the living fruit-cells as suddenly die, or will they continue to live as yeast lives, by extracting oxygen from the saccharine juices round them? This is a question of extreme theoretic significance. It was first answered affirmatively by the able and conclusive experiments of Lechartier and Bellamy, and the answer was subsequently confirmed and explained by the experiments and the reasoning of Pasteur. Bérard only showed the absorption of oxygen and the production of carbonic acid; Lechartier and Bellamy proved the production of alcohol, thus completing the evidence that it was a case of real fermentation, though the common alcoholic ferment was absent. So full was Pasteur of the idea that the cells of a fruit would continue to live at the expense of the sugar of the fruit, that once in his laboratory, while conversing on these subjects with M. Dumas, he exclaimed, "I will wager that if a grape be plunged into an atmosphere of carbonic acid, it will produce alcohol and carbonic acid by the continued life of its own cells—that they will act for a time like the cells of the true alcoholic leaven." He

made the experiment, and found the result to be what he had foreseen. He then extended the inquiry. Placing under a bell-jar twenty-four plums, he filled the jar with carbonic acid gas; beside it he placed twenty-four similar plums uncovered. At the end of eight days, he removed the plums from the jar, and compared them with the others. The difference was extraordinary. The uncovered fruits had become soft, watery, and very sweet; the others were firm and hard, their fleshy portions being not at all watery. They had, moreover, lost a considerable quantity of their sugar. They were afterward bruised, and the juice was distilled. It yielded six and a half grams of alcohol, or one per cent of the total weight of the plums. Neither in these plums, nor in the grapes first experimented on by Pasteur, could any trace of the ordinary alcoholic leaven be found. As previously proved by Lechartier and Bellamy, the fermentation was the work of the living cells of the fruit itself, after air had been denied to them. When, moreover, the cells were destroyed by bruising, no fermentation ensued. The fermentation was the correlative of a vital act, and it ceased when life was extinguished.

Lüdersdorf was the first to show by this method that yeast acted, not, as Liebig had assumed, in virtue of its *organic*, but in virtue of its *organized* character. He destroyed the cells of yeast by rubbing them on a ground glass plate, and found that with the destruction of the organism, though its chemical constituents remained, the power to act as a ferment totally disappeared.

One word more in reference to Liebig may find a place here. To the philosophic chemist thoughtfully pondering these phenomena, familiar with the conception of molec-

ular motion, and the changes produced by the interactions of purely chemical forces, nothing could be more natural than to see in the process of fermentation a simple illustration of molecular instability, the ferment propagating to surrounding molecular groups the overthrow of its own tottering combinations. Broadly considered, indeed, there is a certain amount of truth in this theory; but Liebig, who propounded it, missed the very kernel of the phenomena when he overlooked or contemned the part played in fermentation by microscopic life. He looked at the matter too little with the eye of the body, and too much with the spiritual eye. He practically neglected the microscope, and was unmoved by the knowledge which its revelations would have poured in upon his mind. His hypothesis, as I have said, was natural—nay it was a striking illustration of Liebig's power to penetrate and unveil molecular actions; but it was an error, and as such has proved an *ignis fatuus* instead of a *pharos* to some of his followers.

I have said that our air is full of the germs of ferments differing from the alcoholic leaven, and sometimes seriously interfering with the latter. They are the weeds of this microscopic garden which often overshadow and choke the flowers. Let us take an illustrative case. Expose milk to the air. It will, after a time, turn sour, separating like blood into clot and serum. Place a drop of this sour milk under a powerful microscope and watch it closely. You see the minute butter-globules animated by that curious quivering motion called the Brownian motion. But let not this attract your attention too much, for it is another motion that we have now to seek. Here and

there you observe a greater disturbance than ordinary among the globules; keep your eye upon the place of tumult, and you will probably see emerging from it a long eel-like organism, tossing the globules aside and wriggling more or less rapidly across the field of the microscope. Familiar with one sample of this organism, which from its motions receives the name of *vibrio*, you soon detect numbers of them. It is these organisms, and other analogous, though apparently motionless, ones, which by decomposing the milk render it sour and putrid. They are the lactic and putrid ferments, as the yeast-plant is the alcoholic ferment of sugar. Keep them and their germs out of your milk and it will continue sweet. But milk may become putrid without becoming sour. Examine such putrid milk microscopically, and you find it swarming with shorter organisms, sometimes associated with the vibrios, sometimes alone, and often manifesting a wonderful alacrity of motion. Keep these organisms and their germs out of your milk and it will never putrefy. Expose a mutton-chop to the air and keep it moist; in summer weather it soon stinks. Place a drop of the juice of the fetid chop under a powerful microscope; it is seen swarming with organisms resembling those in the putrid milk. These organisms, which receive the common name of *bacteria*,[1] are the agents of all putrefaction. Keep them and their germs from your meat and it will remain forever sweet. Thus we begin to see that within the world of life to which we ourselves belong, there is another living world requiring the microscope for its dis-

[1] Doubtless organisms exhibiting grave specific differences are grouped together under this common name.

cernment, but which, nevertheless, has the most important bearing on the welfare of the higher life-world.

And now let us reason together as regards the origin of these bacteria. A granular powder is placed in your hands, and you are asked to state what it is. You examine it, and have, or have not, reason to suspect that seeds of some kind are mixed up in it. To determine this point you prepare a bed in your garden, sow in it the powder, and soon after find a mixed crop of docks and thistles sprouting from your bed. Until this powder was sown neither docks nor thistles ever made their appearance in your garden. You repeat the experiment once, twice, ten times, fifty times. From fifty different beds after the sowing of the powder, you obtain the same crop. What will be your response to the question proposed to you? "I am not in a condition," you would say, "to affirm that every grain of the powder is a dock-seed, or a thistle-seed; but I am in a condition to affirm that both dock and thistle seeds form, at all events, part of the powder." Supposing a succession of such powders to be placed in your hands with grains becoming gradually smaller, until they dwindle to the size of impalpable dust particles; assuming that you treat them all in the same way, and that from every one of them in a few days you obtain a definite crop—it may be clover, it may be mustard, it may be mignonette, it may be a plant more minute than any of these, the smallness of the particles, or of the plants that spring from them, does not affect the validity of the conclusion. Without a shadow of misgiving you would conclude that the powder must have contained the seeds or germs of the life observed. There is not in the range of physical science an experi-

t more conclusive nor an inference safer than this

upposing the powder to be light enough to float in air, and that you are enabled to see it there just as ıly as you saw the heavier powder in the palm of hand. If the dust sown by the air instead of by the l produce a definite living crop, with the same logical · you would conclude that the germs of this crop t be mixed with the dust. To take an illustration: spores of the little plant *Penicillium glaucum*, to h I have already referred, are light enough to float ıe air. A cut apple, a pear, a tomato, a slice of vege- marrow, or, as already mentioned, an old moist boot, sh of paste, or a pot of jam, constitutes a proper soil he *Penicillium*. Now, if it could be proved that the of the air when sown in this soil produces this plant, e, wanting the dust, neither the air, nor the soil, nor together can produce it, it would be obviously just ertain in this case that the floating dust contains the ıs of *Penicillium* as that the powders sown in your en contained the germs of the plants which sprung them.

But how is the floating dust to be rendered visible? his way. Build a little chamber and provide it with oor, windows, and window-shutters. Let an aperture nade in one of the shutters through which a sunbeam pass. Close the door and windows so that no light l enter save through the hole in the shutter. The k of the sunbeam is at first perfectly plain and vivid he air of the room. If all disturbance of the air of chamber be avoided, the luminous track will become ter and fainter, until at last it disappears absolutely,

and no trace of the beam is to be seen. What rendered the beam visible at first? The floating dust of the air, which, thus illuminated and observed, is as palpable to sense as dust or powder placed on the palm of the hand. In the still air the dust gradually sinks to the floor or sticks to the walls and ceiling, until finally, by this self-cleansing process, the air is entirely freed from mechanically suspended matter.

Thus far, I think, we have made our footing sure. Let us proceed. Chop up a beefsteak and allow it to remain for two or three hours just covered with warm water; you thus extract the juice of the beef in a concentrated form. By properly boiling the liquid and filtering it, you can obtain from it a perfectly transparent beef-tea. Expose a number of vessels containing this tea to the moteless air of your chamber; and expose a number of vessels containing precisely the same liquid to the dust-laden air. In three days every one of the latter stinks, and, examined with the microscope, every one of them is found swarming with the bacteria of putrefaction. After three months, or three years, the beef-tea within the chamber is found in every case as sweet and clear, and as free from bacteria, as it was at the moment when it was first put in. There is absolutely no difference between the air within and that without save that the one is dustless and the other dust-laden. Clinch the experiment thus: Open the door of your chamber and allow the dust to enter it. In three days afterward you have every vessel within the chamber swarming with bacteria, and in a state of active putrefaction. Here, also, the inference is quite as certain as in the case of the powder sown in your garden. Multiply your proofs by building fifty chambers instead of

one, and by employing every imaginable infusion of wild animals and tame; of flesh, fish, fowl, and viscera; of vegetables of the most various kinds. If in all these cases you find the dust infallibly producing its crop of bacteria, while neither the dustless air nor the nutritive infusion, nor both together, are ever able to produce this crop, your conclusion is simply irresistible that the dust of the air contains the germs of the crop which has appeared in your infusions. I repeat there is no inference of experimental science more certain than this one. In the presence of such facts, to use the words of a paper lately published in the "Philosophical Transactions," it would be simply monstrous to affirm that these swarming crops of bacteria are spontaneously generated.

Is there then no experimental proof of spontaneous generation? I answer without hesitation, *none!* But to doubt the experimental proof of a fact, and to deny its possibility, are two different things, though some writers confuse matters by making them synonymous. In fact, this doctrine of spontaneous generation, in one form or another, falls in with the theoretic beliefs of some of the foremost workers of this age; but it is exactly these men who have the penetration to see, and the honesty to expose, the weakness of the evidence adduced in its support.

And here observe how these discoveries tally with the common practices of life. Heat kills the bacteria, cold numbs them. When my housekeeper has pheasants in charge which she wishes to keep sweet, but which threaten to give way, she partially cooks the birds, kills the inf bacteria, and thus postpones the evil day. By boil milk she also extends its period of sweetness. Some weeks

ago in the Alps I made a few experiments on the influence of cold upon ants. Though the sun was strong, patches of snow still maintained themselves on the mountain slopes. The ants were found in the warm grass and on the warm rocks adjacent. Transferred to the snow the rapidity of their paralysis was surprising. In a few seconds a vigorous ant, after a few languid struggles, would wholly lose its power of locomotion and lie practically dead upon the snow. Transferred to the warm rock, it would revive, to be again smitten with death-like numbness when retransferred to the snow. What is true of the ant is specially true of our bacteria. Their active life is suspended by cold, and with it their power of producing or continuing putrefaction. This is the whole philosophy of the preservation of meat by cold. The fishmonger, for example, when he surrounds his very assailable wares by lumps of ice, stays the process of putrefaction by reducing to numbness and inaction the organisms which produce it, and in the absence of which his fish would remain sweet and sound. It is the astonishing activity into which these bacteria are pushed by warmth that renders a single summer's day sometimes so disastrous to the great butchers of London and Glasgow. The bodies of guides lost in the crevasses of Alpine glaciers have come to the surface forty years after their interment, without the flesh showing any sign of putrefaction. But the most astonishing case of this kind is that of the hairy elephant of Siberia which was found incased in ice. It had been buried for ages, but when laid bare its flesh was sweet, and for some time afforded copious nutriment to the wild beasts which fed upon it.

Beer is assailable by all the organisms here referred to,

some of which produce acetic, some lactic, and some butyric acid, while yeast is open to attack from the bacteria of putrefaction. In relation to the particular beverage the brewer wishes to produce, these foreign ferments have been properly called *ferments of disease.* The cells of the true leaven are globules, usually somewhat elongated. The other organisms are more or less rod-like or eel-like in shape, some of them being beaded so as to resemble necklaces. Each of these organisms produces a fermentation and a flavor peculiar to itself. Keep them out of your beer and it remains forever unaltered. Never without them will your beer contract disease. But their germs are in the air, in the vessels employed in the brewery; even in the yeast used to impregnate the wort. Consciously or unconsciously, the art of the brewer is directed against them. His aim is to paralyze, if he cannot annihilate them.

For beer, moreover, the question of temperature is one of supreme importance; indeed, the recognized influence of temperature is causing on the continent of Europe a complete revolution in the manufacture of beer. When I was a student in Berlin, in 1851, there were certain places specially devoted to the sale of Bavarian beer, which was then making its way into public favor. This beer is prepared by what is called the process of *low fermentation;* the name being given partly because the yeast of the beer, instead of rising to the top and issuing through the bunghole, falls to the bottom of the cask; but partly, also, because it is produced at a low temperature. The other and older process, called *high fermentation,* is far more handy, expeditious, and cheap. In high fermentation eight days suffice for the production of the beer; in

low fermentation, ten, fifteen, even twenty days are found necessary. Vast quantities of ice, moreover, are consumed in the process of low fermentation. In the single brewery of Dreher, of Vienna, a hundred million pounds of ice are consumed annually in cooling the wort and beer. Notwithstanding these obvious and weighty drawbacks, the low fermentation is rapidly displacing the high upon the Continent. Here are some statistics which show the number of breweries of both kinds existing in Bohemia in 1860, 1865, and 1870:

	1860	1865	1870
High Fermentation	281	81	18
Low Fermentation	135	459	831

Thus in ten years the number of high-fermentation breweries fell from 281 to 18, while the number of low-fermentation breweries rose from 135 to 831. The sole reason for this vast change—a change which involves a great expenditure of time, labor and money—is the additional command which it gives the brewer over the fortuitous ferments of disease. These ferments, which, it is to be remembered, are living organisms, have their activity suspended by temperatures below 10° C., and as long as they are reduced to torpor the beer remains untainted either by acidity or putrefaction. The beer of low fermentation is brewed in winter, and kept in cool cellars; the brewer being thus enabled to dispose of it at his leisure, instead of forcing its consumption to avoid the loss involved in its alteration if kept too long. Hops, it may be remarked, act to some extent as an antiseptic to beer. The essential oil of the hop is bactericidal: hence the strong impregnation with hop juice of all beer intended for exportation.

These low organisms, which one might be disposed to regard as the beginnings of life, were we not warned that the microscope, precious and perfect as it is, has no power to show us the real beginnings of life, are by no means purely useless or purely mischievous in the economy of nature. They are only noxious when out of their proper place. They exercise a useful and valuable function as the burners and consumers of dead matter, animal and vegetable, reducing such matter, with a rapidity otherwise unattainable, to innocent carbonic acid and water. Furthermore, they are not all alike, and it is only restricted classes of them that are really dangerous to man. One difference in their habits is worthy of special reference here. Air, or rather the oxygen of the air, which is absolutely necessary to the support of the bacteria of putrefaction, is, according to Pasteur, absolutely deadly to the vibrios which provoke the butyric acid fermentation. This has been illustrated by the following beautiful observation.

A drop of the liquid containing those small organisms is placed upon glass, and on the drop is placed a circle of exceedingly thin glass; for, to magnify them sufficiently, it is necessary that the object-glass of the microscope should come very close to the organisms. Round the edge of the circular plate of glass the liquid is in contact with the air, and incessantly absorbs it, including the oxygen. Here, if the drop be charged with bacteria, we have a zone of very lively ones. But through this living zone, greedy of oxygen and appropriating it, the vivifying gas cannot penetrate to the centre of the film. In the middle, therefore, the bacteria die, while their peripheral colleagues continue active. If a bubble of air chance to

be enclosed in the film, round it the bacteria will pirouette and wabble until its oxygen has been absorbed, after which all their motions cease. Precisely the reverse of all this occurs with the vibrios of butyric acid. In their case it is the peripheral organisms that are first killed, the central ones remaining vigorous while ringed by a zone of dead. Pasteur, moreover, filled two vessels with a liquid containing these vibrios; through one vessel he led air, and killed its vibrios in half an hour; through the other he led carbonic acid, and after three hours found the vibrios fully active. It was while observing these differences of deportment fifteen years ago that the thought of life without air, and its bearing upon the theory of fermentation, flashed upon the mind of this admirable investigator.

We now approach an aspect of this question which concerns us still more closely, and will be best illustrated by an actual fact. A few years ago I was bathing in an Alpine stream, and returning to my clothes from the cascade which had been my shower-bath, I slipped upon a block of granite, the sharp crystals of which stamped themselves into my naked shin. The wound was an awkward one, but being in vigorous health at the time, I hoped for a speedy recovery. Dipping a clean pocket handkerchief into the stream, I wrapped it round the wound, limped home, and remained for four or five days quietly in bed. There was no pain, and at the end of this time I thought myself quite fit to quit my room. The wound, when uncovered, was found perfectly clean, uninflamed, and entirely free from matter. Placing over it a bit of goldbeater's-skin, I walked about all day. Toward evening itching and heat were felt; a large accumulation of

matter followed, and I was forced to go to bed again. The water bandage was restored, but it was powerless to check the action now set up; arnica was applied, but it made matters worse. The inflammation increased alarmingly, until finally I had to be carried on men's shoulders down the mountain and transported to Geneva, where, thanks to the kindness of friends, I was immediately placed in the best medical hands. On the morning after my arrival in Geneva, Dr. Gautier discovered an abscess in my instep, at a distance of five inches from the wound. The two were connected by a channel, or *sinus*, as it is technically called, through which he was able to empty the abscess, without the application of the lance.

By what agency was that channel formed—what was it that thus tore asunder the sound tissue of my instep, and kept me for six weeks a prisoner in bed? In the very room where the water dressing had been removed from my wound and the goldbeater's-skin applied to it, I opened this year a number of tubes, containing perfectly clear and sweet infusions of fish, flesh, and vegetable. These hermetically sealed infusions had been exposed for weeks, both to the sun of the Alps and to the warmth of a kitchen, without showing the slightest turbidity or sign of life. But two days after they were opened the greater number of them swarmed with the bacteria of putrefaction, the germs of which had been contracted from the dust-laden air of the room. And had the matter from my abscess been examined, my memory of its appearance leads me to infer that it would have been found equally swarming with these bacteria—that it was their germs which got into my incautiously opened wound, and that they were the subtile workers that burrowed down my

shin, dug the abscess in my instep, and produced effects which might easily have proved fatal.

This apparent digression brings us face to face with the labors of a man who combines the penetration of the true theorist with the skill and conscientiousness of the true experimenter, and whose practice is one continued demonstration of the theory that the putrefaction of wounds is to be averted by the destruction of the germs of bacteria. Not only from his own reports of his cases, but from the reports of eminent men who have visited his hospital, and from the opinions expressed to me by continental surgeons, do I gather that one of the greatest steps ever made in the art of surgery was the introduction of the antiseptic system of treatment, introduced by Professor Lister.

The interest of this subject does not slacken as we proceed. We began with the cherry-cask and beer-vat; we end with the body of man. There are persons born with the power of interpreting natural facts, as there are others smitten with everlasting incompetence in regard to such interpretation. To the former class in an eminent degree belonged the illustrious philosopher Robert Boyle, whose words in relation to this subject have in them the forecast of prophecy. "And let me add," writes Boyle in his "Essay on the Pathological Part of Physik," "that he that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them, to give a fair account of divers phenomena of several diseases (as well fevers as others) which will perhaps be never properly understood without an insight into the doctrine of fermentations."

Two hundred years have passed since these pregnant words were written, and it is only in this our day th

nen are beginning to fully realize their truth. In the lomain of surgery the justice of Boyle's surmise has been nost strictly demonstrated. But we now pass the bounds f surgery proper, and enter the domain of epidemic disase, including those fevers so sagaciously referred to by Boyle. The most striking analogy between a *contagium* nd a ferment is to be found in the power of indefinite elf-multiplication possessed and exercised by both. You now the exquisitely truthful figures regarding leaven emloyed in the New Testament. A particle hid in three neasures of meal leavens it all. A little leaven leaveneth he whole lump. In a similar manner, a particle of *conagium* spreads through the human body and may be so nultiplied as to strike down whole populations. Consider he effect produced upon the system by a microscopic uantity of the virus of smallpox. That virus is, to all ntents and purposes, a seed. It is sown as yeast is sown, t grows and multiplies as yeast grows and multiplies, and t always reproduces itself. To Pasteur we are indebted or a series of masterly researches, wherein he exposes the ooseness and general baselessness of prevalent notions regarding the transmutation of one ferment into another. Ie guards himself against saying it is impossible. The rue investigator is sparing in the use of this word, though he use of it is unsparingly ascribed to him; but, as a natter of fact, Pasteur has never been able to effect the lleged transmutation, while he has been always able to oint out the open doorways through which the affirmers f such transmutations had allowed error to march in pon them.[1]

[1] Those who wish for an illustration of the care necessary in these researches, and of the carelessness with which they have in some cases been

The great source of error here has been already alluded to in this discourse. The observers worked in an atmosphere charged with the germs of different organisms; the mere accident of first possession rendering now one organism, now another, triumphant. In different stages, moreover, of its fermentative or putrefactive changes, the same infusion may so alter as to be successively taken possession of by different organisms. Such cases have been adduced to show that the earlier organisms must have been transformed into the later ones, whereas they are simply cases in which different germs, because of changes in the infusion, render themselves valid at different times.

By teaching us how to cultivate each ferment in its purity—in other words, by teaching us how to rear the individual organism apart from all others—Pasteur has enabled us to avoid all these errors. And where this isolation of a particular organism has been duly effected it grows and multiplies indefinitely, but no change of it into another organism is ever observed. In Pasteur's researches the Bacterium remained a Bacterium, the Vibrio a Vibrio, the Penicillium a Penicillium, and the Torula a Torula. Sow any of these in a state of purity in an appropriate liquid; you get it, and it alone, in the subsequent crop. In like manner, sow smallpox in the human body, your crop is smallpox. Sow there scarlatina, and your crop is scarlatina. Sow typhoid virus, your crop is typhoid—cholera, your crop is cholera. The disease bears as constant a relation to its contagium as the microscopic organisms just enumerated do to their germs, or indeed as

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conducted, will do well to consult the Rev. W. H. Dallinger's excellent "Notes on Heterogenesis" in the October number of the "Popular Science Review."

a thistle does to its seed. No wonder then, with analogies so obvious and so striking, that the conviction is spreading and growing daily in strength, that reproductive parasitic life is at the root of epidemic disease—that living ferments finding lodgment in the body increase there and multiply, directly ruining the tissue on which they subsist, or destroying life indirectly by the generation of poisonous compounds within the body. This conclusion, which comes to us with a presumption almost amounting to demonstration, is clinched by the fact that virulently infective diseases have been discovered with which living organisms are as closely and as indissolubly associated as the growth of Torula is with the fermentation of beer.

And here, if you will permit me, I would utter a word of warning to well-meaning people. We have now reached a phase of this question when it is of the very last importance that light should once for all be thrown upon the manner in which contagious and infectious diseases take root and spread. To this end the action of various ferments upon the organs and tissues of the living body must be studied; the habitat of each special organism concerned in the production of each specific disease must be determined, and the mode by which its germs are spread abroad as sources of further infection. It is only by such rigidly accurate inquiries that we can obtain final and complete mastery over these destroyers. Hence, while abhorring cruelty of all kinds, while shrinking sympathetically from all animal suffering—suffering which my own pursuits never call upon me to inflict—an unbiased survey of the field of research now opening out before the physiologist causes me to conclude that no greater calamity could befall the human race than the stoppage

of experimental inquiry in this direction. A lady whose philanthropy has rendered her illustrious said to me some time ago that science was becoming immoral; that the researches of the past, unlike those of the present, were carried on without cruelty. I replied to her that the science of Kepler and Newton, to which she referred, dealt with the laws and phenomena of inorganic nature; but that one great advance made by modern science was in the direction of biology, or the science of life; and that in this new direction scientific inquiry, though at the outset pursued at the cost of some temporary suffering, would in the end prove a thousand times more beneficent than it had ever hitherto been. I said this because I saw that the very researches which the lady deprecated were leading us to such a knowledge of epidemic diseases as will enable us finally to sweep these scourges of the human race from the face of the earth.

This is a point of such capital importance that I should like to bring it home to your intelligence by a single trustworthy illustration. In 1850, two distinguished French observers, MM. Davainne and Rayer, noticed in the blood of animals which had died of the virulent disease called *splenic fever* small microscopic organisms resembling transparent rods, but neither of them at that time attached any significance to the observation. In 1861, Pasteur published a memoir on the fermentation of butyric acid, wherein he described the organism which provoked it, and after reading this memoir it occurred to Davainne that splenic fever might be a case of fermentation set up within the animal body by the organisms which had been observed by him and Rayer. This idea has been placed beyond all doubt by subsequent research.

Observations of the highest importance have also been made on splenic fever by Pollender and Brauell. Two years ago, Dr. Burdon Sanderson gave us a very clear account of what was known up to that time of this disorder. With regard to the permanence of the contagium, it had been proved to hang for years about localities where it had once prevailed; and this seemed to show that the rod-like organisms could not constitute the contagium, because their infective power was found to vanish in a few weeks. But other facts established an intimate connection between the organisms and the disease, so that a review of all the facts caused Dr. Sanderson to conclude that the contagium existed in two distinct forms: the one "fugitive" and visible as transparent rods; the other permanent but "latent," and not yet brought within the grasp of the microscope.

At the time that Dr. Sanderson was writing this report, a young German physician named Koch,[1] occupied with the duties of his profession in an obscure country district, was already at work, applying, during his spare time, various original and ingenious devices to the investigation of splenic fever. He studied the habits of the rod-like organisms, and found the aqueous humor of an ox's eye to be particularly suitable for their nutrition. With a drop of the aqueous humor he mixed the tiniest speck of a liquid containing the rods, placed the drop under his microscope, warmed it suitably, and observed the subsequent action. During the first two hours hardly any change was noticeable; but at the end of this time the rods began to lengthen, and the action was so rapid that

[1] This, I believe, was the first reference to the researches of Koch made in this country. 1879.

at the end of three or four hours they attained from ten to twenty times their original length. At the end of a few additional hours they had formed filaments in many cases a hundred times the length of the original rods. The same filament, in fact, was frequently observed to stretch through several fields of the microscope. Sometimes they lay in straight lines parallel to each other, in other cases they were bent, twisted, and coiled into the most graceful figures; while sometimes they formed knots of such bewildering complexity that it was impossible for the eye to trace the individual filaments through the confusion.

Had the observation ended here an interesting scientific fact would have been added to our previous store, but the addition would have been of little practical value. Koch, however, continued to watch the filaments, and after a time noticed little dots appearing within them. These dots became more and more distinct, until finally the whole length of the organism was studded with minute ovoid bodies, which lay within the outer integument like peas within their shell. By and by the integument fell to pieces, the place of the organisms being taken by a long row of seeds or spores. These observations, which were confirmed in all respects by the celebrated naturalist, Cohn of Breslau, are of the highest importance. They clear up the existing perplexity regarding the latent and visible contagia of splenic fever; for in the most conclusive manner Koch proved the spores, as distinguished from the rods, to constitute the contagium of the fever in its most deadly and persistent form.

How did he reach this important result? Mark the answer. There was but one way open to him to test the

activity of the contagium, and that was the inoculation with it of living animals. He operated upon guinea-pigs and rabbits, but the vast majority of his experiments were made upon mice. Inoculating them with the fresh blood of an animal suffering from splenic fever, they invariably died of the same disease within twenty or thirty hours after inoculation. He then sought to determine how the contagium maintained its vitality. Drying the infectious blood containing the rod-like organisms, in which, however, the spores were not developed, he found the contagium to be that which Dr. Sanderson calls "fugitive." It maintained its power of infection for five weeks at the furthest. He then dried blood containing the fully-developed spores, and exposed the substance to a variety of conditions. He permitted the dried blood to assume the form of dust; wetted this dust, allowed it to dry again, permitted it to remain for an indefinite time in the midst of putrefying matter, and subjected it to various other tests. After keeping the spore-charged blood which had been treated in this fashion for four years, he inoculated a number of mice with it, and found its action as fatal as that of blood fresh from the veins of an animal suffering from splenic fever. There was no single escape from death after inoculation by this deadly contagium. Uncounted millions of these spores are developed in the body of every animal which has died of splenic fever, and every spore of these millions is competent to produce the disease. The name of this formidable parasite is *Bacillus anthracis*.[1]

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[1] Koch found that to produce its characteristic effects the contagium of splenic fever must enter the blood; the virulently infective spleen of a diseased animal may be eaten with impunity by mice. On the other hand, the disease refuses to be communicated by inoculation to dogs, partridges, or sparrows. In

Now the very first step toward the extirpation of these contagia is the knowledge of their nature; and the knowledge brought to us by Dr. Koch will render as certain the stamping out of splenic fever as the stoppage of the plague of *pébrine* by the researches of Pasteur.[1] One small item of statistics will show what this implies. In the single district of Novgorod in Russia, between the years 1867 and 1870, over fifty-six thousand cases of death by splenic fever, among horses, cows, and sheep were recorded. Nor did its ravages confine themselves to the animal world, for during the time and in the district referred to, five hundred and twenty-eight human beings perished in the agonies of the same disease.

A description of the fever will help you to come to a right decision on the point which I wish to submit to your consideration. "An animal," says Dr. Burdon Sanderson, "which perhaps for the previous day has declined food and shown signs of general disturbance, begins to shudder and to have twitches of the muscles of the back, and soon after becomes weak and listless. In the meantime the respiration becomes frequent and often difficult, and the temperature rises three or four degrees above the normal; but soon convulsions, affecting chiefly the muscles of the back and loins, usher in the final collapse of which

their blood *Bacillus anthracis* ceases to act as a ferment. Pasteur announced more than six years ago the propagation of the vibrios of the silkworm disease called *flacherie*, both by fission and by spores. He also made some remarkable experiments on the permanence of the contagium in the form of spores. See "Études sur la Maladie des Vers à Soie," pp. 168 and 256.

[1] Surmising that the immunity enjoyed by birds might arise from the heat of their blood, which destroyed the *bacillus*, Pasteur lowered their temperature artificially, inoculated them, and *killed them*. He also raised the temperature of guinea-pigs after inoculation, and *saved them*. It is needless to dwell for a moment on the importance of this experiment.

the progress is marked by the loss of all power of moving the trunk or extremities, diminution of temperature, mucous and sanguinolent alvine evacuations, and similar discharges from the mouth and nose." In a single district of Russia, as above remarked, fifty-six thousand horses, cows, and sheep, and five hundred and twenty-eight men and women, perished in this way during a period of two or three years. What the annual fatality is throughout Europe I have no means of knowing. Doubtless it must be very great. The question, then, which I wish to submit to your judgment is this: Is the knowledge which reveals to us the nature, and which assures the extirpation, of a disorder so virulent and so vile, worth the price paid for it? It is exceedingly important that assemblies like the present should see clearly the issues at stake in such questions as this, and that the properly informed sense of the community should temper, if not restrain, the rashness of those who, meaning to be tender, become agents of cruelty by the imposition of short-sighted restrictions upon physiological investigations. It is a modern instance of zeal for God, but not according to knowledge, the excesses of which must be corrected by an instructed public opinion.

And now let us cast a backward glance on the field we have traversed, and try to extract from our labors such further profit as they can yield. For more than two thousand years the attraction of light bodies by amber was the sum of human knowledge regarding electricity, and for more than two thousand years fermentation was effected without any knowledge of its cause. In science one discovery grows out of another, and cannot appear without

its proper antecedent. Thus, before fermentation coul be understood, the microscope had to be invented, an brought to a considerable degree of perfection. Note th growth of knowledge. Leeuwenhoek, in 1680, found yeas to be a mass of floating globules, but he had no notion that the globules were alive. This was proved in 1835 by Cagniard de la Tour and Schwann. Then came the question as to the origin of such microscopic organisms, and in this connection the memoir of Pasteur, published in the "Annales de Chimie" for 1862, is the inauguration of a new epoch.

On that investigation all Pasteur's subsequent labors were based. Ravages had over and over again occurred among French wines. There was no guarantee that they would not become acid or bitter, particularly when exported. The commerce in wines was thus restricted, and disastrous losses were often inflicted on the wine-grower. Every one of these diseases was traced to the life of an organism. Pasteur ascertained the temperature which killed these ferments of disease, proving it to be so low as to be perfectly harmless to the wine. By the simple expedient of heating the wine to a temperature of fifty degrees Centigrade, he rendered it unalterable, and thus saved his country the loss of millions. He then went on to vinegar—*vin aigre*, acid wine—which he proved to be produced by a fermentation set up by a little fungus called *Mycoderma aceti*. *Torula*, in fact, converts the grape juice into alcohol, and *Mycoderma aceti* converts the alcohol into vinegar. Here also frequent failures occurred, and severe losses were sustained. Through the operation of unknown causes, the vinegar often became unfit for use, sometimes indeed falling into utter putridity. It had been

long known that mere exposure to the air was sufficient to destroy it. Pasteur studied all these changes, traced them to their living causes, and showed that the permanent health of the vinegar was insured by the destruction of this life. He passed from the diseases of vinegar to the study of a malady which a dozen years ago had all but ruined the silk husbandry of France. This plague, which received the name of *pébrine*, was the product of a parasite which first took possession of the intestinal canal of the silkworm, spread throughout its body, and filled the sack which ought to contain the viscid matter of the silk. Thus smitten, the worm would go automatically through the process of spinning when it had nothing to spin. Pasteur followed this parasitic destroyer from year to year, and led by his singular power of combining facts with the logic of facts, discovered eventually the precise phase in the development of the insect when the disease which assailed it could with certainty be stamped out. Pasteur's devotion to this inquiry cost him dear. He restored to France her silk husbandry, rescued thousands of her population from ruin, set the looms of Italy also to work, but emerged from his labors with one of his sides permanently paralyzed. His last investigation is embodied in a work entitled "Studies on Beer," in which he describes a method of rendering beer permanently unchangeable. That method is not so simple as those found effectual with wine and vinegar, but the principles which it involves are sure to receive extensive application at some future day.

There are other reflections connected with this subject which, even were they now passed over without remark, would sooner or later occur to every thoughtful mind in this assembly. I have spoken of the floating dust of the

air, of the means of rendering it visible, and of the perfect immunity from putrefaction which accompanies the contact of germless infusions and moteless air. Consider the woes which these wafted particles, during historic and prehistoric ages, have inflicted on mankind; consider the loss of life in hospitals from putrefying wounds; consider the loss in places where there are plenty of wounds, but no hospitals, and in the ages before hospitals were anywhere founded; consider the slaughter which has hitherto followed that of the battlefield, when those bacterial destroyers are let loose, often producing a mortality far greater than that of the battle itself; add to this the other conception that in times of epidemic disease the self-same floating matter has frequently, if not always, mingled with it the special germs which produce the epidemic, being thus enabled to sow pestilence and death over nations and continents—consider all this, and you will come with me to the conclusion that all the havoc of war, ten times multiplied, would be evanescent if compared with the ravages due to atmospheric dust.

This preventible destruction is going on to-day, and it has been permitted to go on for ages, without a whisper of information regarding its cause being vouchsafed to the suffering sentient world. We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only to-day that the light of science is being let in upon the murderous dominion of our foes. Facts like these excite in me the thought that the rule and governance of this universe are different from what we in our youth supposed them to be—that the inscrutable Power, at once terrible and beneficent, in whom we live and move and have our being and our end, is to be propitiated by means

different to those usually resorted to. The first requisite toward such propitiation is *knowledge;* the second is *action,* shaped and illuminated by that knowledge. Of knowledge we already see the dawn, which will open out by and by to perfect day; while the action which is to follow has its unfailing source and stimulus in the moral and emotional nature of man—in his desire for personal well-being, in his sense of duty, in his compassionate sympathy with the sufferings of his fellow-men. "How often," says Dr. William Budd in his celebrated work on Typhoid Fever—"How often have I seen in past days, in the single narrow chamber of the day-laborer's cottage the father in the coffin, the mother in the sick-bed in muttering delirium, and nothing to relieve the desolation of the children but the devotion of some poor neighbor, who in too many cases paid the penalty of her kindness in becoming herself the victim of the same disorder!" From the vantage ground already won I look forward with confident hope to the triumph of medical art over scenes of misery like that here described. The cause of the calamity being once clearly revealed, not only to the physician, but to the public, whose intelligent co-operation is absolutely essential to success, the final victory of humanity is only a question of time. We have already a foretaste of that victory in the triumphs of surgery as practiced at your doors.

XIII

SPONTANEOUS GENERATION[1]

WITHIN ten minutes' walk of a little cottage which I have recently built in the Alps, there is a small lake, fed by the melted snows of the upper mountains. During the early weeks of summer no trace of life is to be discerned in this water; but invariably toward the end of July, or the beginning of August, swarms of tailed organisms are seen enjoying the sun's warmth along the shallow margins of the lake, and rushing with audible patter into deeper water at the approach of danger. The origin of this periodic crowd of living things is by no means obvious. For years I had never noticed in the lake either an adult frog, or the smallest fragment of frog spawn; so that, were I not otherwise informed, I should have found the conclusion of Mathiole a natural one, namely, that tadpoles are generated in lake mud by the vivifying action of the sun.

The checks which experience alone can furnish being absent, the spontaneous generation of creatures quite as high as the frog in the scale of being was assumed for ages to be a fact. Here, as elsewhere, the dominant mind of Aristotle stamped its notions on the world at large. For nearly twenty centuries after him men found no difficulty in believing in cases of spontaneous generation which

[1] "The Nineteenth Century," January, 1878.

ould now be rejected as monstrous by the most fanatical
pporter of the doctrine. Shell-fish of all kinds were
nsidered to be without parental origin. Eels were sup-
sed to spring spontaneously from the fat ooze of the
ile. Caterpillars were the spontaneous products of the
aves on which they fed; while winged insects, serpents,
ts, and mice were all thought capable of being generated
ithout sexual intervention.

The most copious source of this life without an ancestry
as putrefying flesh; and, lacking the checks imposed by
ller investigation, the conclusion that flesh possesses and
erts this generative power is a natural one. I well re-
ember when a child of ten or twelve seeing a joint of
perfectly salted beef cut into, and coils of maggots laid
re within the mass. Without a moment's hesitation I
mped to the conclusion that these maggots had been
ontaneously generated in the meat. I had no knowledge
hich could qualify or oppose this conclusion, and for the
me it was irresistible. The childhood of the individual
pifies that of the race, and the belief here enunciated
as that of the world for nearly two thousand years.

To the examination of this very point the celebrated
ancesco Redi, physician to the Granddukes Ferdinand
. and Cosmo III. of Tuscany, and a member of the
cademy del Cimento, addressed himself in 1668. He
d seen the maggots of putrefying flesh, and reflected
their possible origin. But he was not content with
ere reflection, nor with the theoretic guesswork which
s predecessors had founded upon their imperfect obser-
tions. Watching meat during its passage from fresh-
ss to decay, prior to the appearance of maggots he
variably observed flies buzzing round the meat and fre-

quently alighting on it. The maggots, he thought, might be the half-developed progeny of these flies.

The inductive guess precedes experiment, by which, however, it must be finally tested. Redi knew this, and acted accordingly. Placing fresh meat in a jar and covering the mouth with paper, he found that, though the meat putrefied in the ordinary way, it never bred maggots, while the same meat placed in open jars soon swarmed with these organisms. For the paper cover he then substituted fine gauze, through which the odor of the meat could rise. Over it the flies buzzed, and on it they laid their eggs, but, the meshes being too small to permit the eggs to fall through, no maggots were generated in the meat. They were, on the contrary, hatched upon the gauze. By a series of such experiments Redi destroyed the belief in the spontaneous generation of maggots in meat, and with it doubtless many related beliefs. The combat was continued by Vallisneri, Schwammerdam, and Réaumur, who succeeded in banishing the notion of spontaneous generation from the scientific minds of their day. Indeed, as regards such complex organisms as those which formed the subject of their researches, the notion was banished forever.

But the discovery and improvement of the microscope, though giving a death-blow to much that had been previously written and believed regarding spontaneous generation, brought also into view a world of life formed of individuals so minute—so close as it seemed to the ultimate particles of matter—as to suggest an easy passage from atoms to organisms. Animal and vegetable infusions exposed to the air were found clouded and crowded with creatures far beyond the reach of unaided vision, but per-

ly visible to an eye strengthened by the microscope. h reference to their origin these organisms were called fusoria." Stagnant pools were found full of them, and obvious difficulty of assigning a germinal origin to exces so minute furnished the precise condition necesto give new play to the notion of heterogenesis or taneous generation.

The scientific world was soon divided into two hostile ps, the leaders of which only can here be briefly ald to. On the one side, we have Buffon and Need-, the former postulating his "organic molecules," and latter assuming the existence of a special "vegetative e" which drew the molecules together so as to form g things. On the other side, we have the celebrated é Lazzaro Spallanzani, who in 1777 published results ter to those announced by Needham in 1748, and obd by methods so precise as to completely overthrow convictions based upon the labors of his predecessor. ging his flasks with organic infusions, he sealed their s with the blowpipe, subjected them in this condition he heat of boiling water, and subsequently exposed to temperatures favorable to the development of life. infusions continued unchanged for months, and when flasks were subsequently opened no trace of life was d.

Here I may forestall matters so far as to say that the ess of Spallanzani's experiments depended wholly on locality in which he worked. The air around him t have been free from the more obdurate infusorial ns, for otherwise the process he followed would, as long afterward proved by Wyman, have infallibly led life. But his refutation of the doctrine of spon-

taneous generation is not the less valid on this account. Nor is it in any way upset by the fact that others in repeating his experiments obtained life where he obtained none. Rather is the refutation strengthened by such differences. Given two experimenters equally skilful and equally careful, operating in different places on the same infusion, in the same way, and assuming the one to obtain life while the other fails to obtain it; then its well-established absence in the one case proves that some ingredient foreign to the infusion must be its cause in the other.

Spallanzani's sealed flasks contained but small quantities of air, and as oxygen was afterward shown to be generally essential to life, it was thought that the absence of life observed by Spallanzani might have been due to the lack of this vitalizing gas. To dissipate this doubt, Schulze in 1836 half filled a flask with distilled water to which animal and vegetable matters were added. First boiling his infusion to destroy whatever life it might contain, Schulze sucked daily into his flask air which had passed through a series of bulbs containing concentrated sulphuric acid, where all germs of life suspended in the air were supposed to be destroyed. From May to August this process was continued without any development of infusorial life.

Here again the success of Schulze was due to his working in comparatively pure air, but even in such air his experiment is a very risky one. Germs will pass unwetted and unscathed through sulphuric acid unless the most special care is taken to detain them. I have repeatedly failed, by repeating Schulze's experiments, to obtain his results. Others have failed likewise. The air passes in bubbles through the bulbs, and to render the

thod secure, the passage of the air must be so slow as cause the whole of its floating matter, even to the very e of each bubble, to touch the surrounding liquid. But this precaution be observed, water will be found quite effectual as sulphuric acid. By the aid of an air-pump, a highly infective atmosphere, I have thus drawn air weeks without intermission, first through bulbs conning water, and afterward through vessels containing anic infusions, without any appearance of life. The ms were not killed by the water, but they were effectly intercepted, while the objection that the air had been ured by being brought into contact with strongly corive substances was avoided.

The brief paper of Schulze, published in Poggendorf's nnalen" for 1836, was followed in 1837 by another rt and pregnant communication by Schwann. Redi, as have seen, traced the maggots of putrefying flesh to the s of flies. But he did not and he could not know the aning of putrefaction itself. He had not the instrantal means to inform him that *it* also is a phenomenon endant on the development of life. This was first ved in the paper now alluded to. Schwann placed h in a flask filled to one-third of its capacity with er, sterilized the flask by boiling, and then supplied for months with calcined air. Throughout this time re appeared no mould, no infusoria, no putrefaction; flesh remained unaltered, while the liquid continued clear as it was immediately after boiling. Schwann n varied his experimental argument, with no altera in the result. His final conclusion was that putrefac is due to decompositions of organic matter attendant the multiplication therein of minute organisms. These

organisms were derived not from the air, but from something contained in the air, which was destroyed by a sufficiently high temperature. There never was a more determined opponent of the doctrine of spontaneous generation than Schwann, though a strange attempt was made a year and a half ago to enlist him and others equally opposed to it on the side of the doctrine.

The physical character of the agent which produces putrefaction was further revealed by Helmholtz in 1843. By means of a membrane he separated a sterilized putrescible liquid from a putrefying one. The sterilized infusion remained perfectly intact. Hence it was not the liquid of the putrefying mass—for that could freely diffuse through the membrane—but something contained in the liquid, and which was stopped by the membrane, that caused the putrefaction. In 1854 Schroeder and Von Dusch struck into this inquiry, which was subsequently followed up by Schroeder alone. These able experimenters employed plugs of cotton-wool to filter the air supplied to their infusions. Fed with such air, in the great majority of cases the putrescible liquids remained perfectly sweet after boiling. Milk formed a conspicuous exception to the general rule. It putrefied after boiling, though supplied with carefully filtered air. The researches of Schroeder bring us up to the year 1859.

In that year a book was published which seemed to overturn some of the best established facts of previous investigators. Its title was "Hétérogénie," and its author was F. A. Pouchet, Director of the Museum of Natural History at Rouen. Ardent, laborious, learned, full not only of scientific, but of metaphysical fervor, he threw his whole energy into the inquiry. Never did a subject re-

quire the exercise of the cold critical faculty more than this one—calm study in the unravelling of complex phenomena, care in the preparation of experiments, care in their execution, skilful variation of conditions, and incessant questioning of results until repetition had placed them beyond doubt or question. To a man of Pouchet's temperament the subject was full of danger—danger not lessened by the theoretic bias with which he approached it. This is revealed by the opening words of his preface: "Lorsque, par la méditation, il fut évident pour moi que la génération spontanée était encore l'un des moyens qu'emploie la nature pour la reproduction des êtres, je m'appliquai à découvrir par quels procédés on pouvait parvenir à en mettre les phénomènes en évidence." It is needless to say that such a prepossession required a strong curb. Pouchet repeated the experiments of Schulze and Schwann with results diametrically opposed to theirs. He heaped experiment upon experiment and argument upon argument, spicing with the sarcasm of the advocate the logic of the man of science. In view of the multitudes required to produce the observed results, he ridiculed the assumption of atmospheric germs. This was one of his strongest points. "Si les Proto-organismes que nous voyons pulluler partout et dans tout, avaient leurs germes disséminés dans l'atmosphère, dans la proportion mathématiquement indispensable à cet effet, l'air en serait totalement obscurci, car ils devraient s'y trouver beaucoup plus serrés que les globules d'eau qui forment nos nuages épais. Il n'y a pas là la moindre exagération." Recurring to the subject, he exclaims: "L'air dans lequel nous vivons aurait presque la densité du fer." There is often a virulent contagion in a confident tone, and this hardi-

hood of argumentative assertion was sure to influence minds swayed not by knowledge, but by authority. Had Pouchet known that "the blue ethereal sky" is formed of suspended particles, through which the sun freely shines, he would hardly have ventured upon this line of argument.

Pouchet's pursuit of this inquiry strengthened the conviction with which he began it, and landed him in downright credulity in the end. I do not question his ability as an observer, but the inquiry needed a disciplined experimenter. This latter implies not mere ability to look at things as Nature offers them to our inspection, but to force her to show herself under conditions prescribed by the experimenter himself. Here Pouchet lacked the necessary discipline. Yet the vigor of his onset raised clouds of doubt, which for a time obscured the whole field of inquiry. So difficult indeed did the subject seem, and so incapable of definite solution, that when Pasteur made known his intention to take it up, his friends Biot and Dumas expressed their regret, earnestly exhorting him to set a definite and rigid limit to the time he purposed spending in this apparently unprofitable field.[1]

Schooled by his education as a chemist, and by special researches on the closely related question of fermentation, Pasteur took up this subject under particularly favorable conditions. His work and his culture had given strength and finish to his natural aptitudes. In 1862, accordingly, he published a paper "On the Organized Corpuscles exist-

[1] "Je ne conseillerais à personne," said Dumas to his already famous pupil, "de rester trop longtemps dans ce sujet."—"Annales de Chimie et de Physique," 1862, vol. lxiv. p. 22. Since that time the illustrious Perpetual Secretary of the Academy of Sciences has had good reason to revise this "counsel."

ing in the Atmosphere," which must forever remain classical. By the most ingenious devices he collected the floating particles of the air surrounding his laboratory in the Rue d'Ulm, and subjected them to microscopic examination. Many of them he found to be organized particles. Sowing them in sterilized infusions, he obtained abundant crops of microscopic organisms. By more refined methods he repeated and confirmed the experiments of Schwann, which had been contested by Pouchet, Montegazza, Joly, and Musset. He also confirmed the experiments of Schroeder and Von Dusch. He showed that the cause which communicated life to his infusions was not uniformly diffused through the air; that there were aërial interspaces which possessed no power to generate life. Standing on the Mer de Glace, near the Montanvert, he snipped off the ends of a number of hermetically sealed flasks containing organic infusions. One out of twenty of the flasks thus supplied with glacier air showed signs of life afterward, while eight out of twenty of the same infusions, supplied with the air of the plains, became crowded with life. He took his flasks into the caves under the Observatory of Paris, and found the still air in these caves devoid of generative power. These and other experiments, carried out with a severity perfectly obvious to the instructed scientific reader, and accompanied by a logic equally severe, restored the conviction that, even in these lower reaches of the scale of being, life does not appear without the operation of antecedent life.

The main position of Pasteur has been strengthened by practical researches of the most momentous kind. He has applied the knowledge won from his inquiries to the preservation of wine and beer, to the manufacture of vin-

egar, to the staying of the plague which threatened utter destruction of the silk husbandry of France, and to the examination of other formidable diseases which assail the higher animals, including man. His relation to the improvements which Professor Lister has introduced into surgery is shown by a letter quoted in his "Etudes sur la Bière."[1] Professor Lister there expressly thanks Pasteur for having given him the only principle which could have conducted the antiseptic system to a successful issue. The strictures regarding defects of reasoning, to which we have been lately accustomed, throw abundant light upon their author, but no shade upon Pasteur.

Redi, as we have seen, proved the maggots of putrefying flesh to be derived from the eggs of flies; Schwann proved putrefaction itself to be the concomitant of far lower forms of life than those dealt with by Redi. Our knowledge here, as elsewhere in connection with this subject, has been vastly extended by Professor Cohn, of Breslau. "No putrefaction," he says, "can occur in a nitrogenous substance if its bacteria be destroyed and new ones prevented from entering it. Putrefaction begins as soon as bacteria, even in the smallest numbers, are admitted either accidentally or purposely. It progresses in direct proportion to the multiplication of the bacteria, it is retarded when they exhibit low vitality, and is stopped by all influences which either hinder their development or kill them. All bactericidal media are therefore antiseptic and disinfecting."[2] It was these organisms acting in

[1] P. 43.

[2] In his last excellent memoir Cohn expresses himself thus: "Wer noch heut die Fäulniss von einer spontanen Dissociation der Proteinmolecule, oder von einem unorganisirten Ferment ableitet, oder gar aus 'Stickstoffsplittern'

wound and abscess which so frequently converted our hospitals into charnel-houses, and it is their destruction by the antiseptic system that now renders justifiable operations which no surgeon would have attempted a few years ago. The gain is immense—to the practicing surgeon as well as to the patient practiced upon. Contrast the anxiety of never feeling sure whether the most brilliant operation might not be rendered nugatory by the access of a few particles of unseen hospital dust, with the comfort derived from the knowledge that all power of mischief on the part of such dust has been surely and certainly annihilated. But the action of living contagia extends beyond the domain of the surgeon. The power of reproduction and indefinite self-multiplication which is characteristic of living things, coupled with the undeviating fact of contagia "breeding true," has given strength and consistency to a belief long entertained by penetrating minds, that epidemic diseases generally are the concomitants of parasitic life. "There begins to be faintly visible to us a vast and destructive laboratory of nature wherein the diseases which are most fatal to animal life, and the changes to which dead organic matter is passively liable, appear bound together by what must at least be called a very close analogy of causation."[1] According to this view, which, as I have said, is daily gaining converts, a contagious disease may be defined as a conflict between the person smitten by it and a specific organism which multiplies at his expense, appropriating his air and moisture,

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die Balken zur Stütze seiner Fäulnisstheorie zu zimmern versucht, hat zuerst den Satz 'keine Fäulniss ohne Bacterium Termo' zu widerlegen."

[1] Report of the Medical Officer of the Privy Council, 1874, p. 5.

disintegrating his tissues, or poisoning him by the decompositions incident to its growth.

During the ten years extending from 1859 to 1869, researches on radiant heat in its relations to the gaseous form of matter occupied my continual attention. When air was experimented on, I had to cleanse it effectually of floating matter, and while doing so I was surprised to notice that, at the ordinary rate of transfer, such matter passed freely through alkalies, acids, alcohols, and ethers. The eye being kept sensitive by darkness, a concentrated beam of light was found to be a most searching test for suspended matter both in water and in air—a test indeed indefinitely more searching and severe than that furnished by the most powerful microscope. With the aid of such a beam I examined air filtered by cotton-wool; air long kept free from agitation, so as to allow the floating matter to subside; calcined air, and air filtered by the deeper cells of the human lungs. In all cases the correspondence between my experiments and those of Schroeder, Pasteur, and Lister in regard to spontaneous generation was perfect. The air which they found inoperative was proved by the luminous beam to be optically pure and therefore germless. Having worked at the subject both by experiment and reflection, on Friday evening, January 21, 1870, I brought it before the members of the Royal Institution. Two or three months subsequently, for sufficient practical reasons, I ventured to direct public attention to the subject in a letter to the "Times." Such was my first contact with this important question.

This letter, I believe, gave occasion for the first public utterance of Dr. Bastian in relation to this subject. He

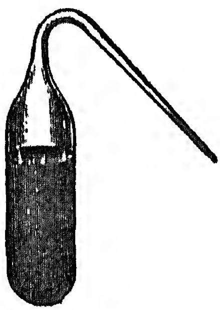
did me the honor to inform me, as others had informed Pasteur, that the subject "pertains to the biologist and physician." He expressed "amazement" at my reasoning and warned me that before what I had done could be undone "much irreparable mischief might be occasioned." With far less preliminary experience to guide and warn him, the English heterogenist was far bolder than Pouchet in his experiments, and far more adventurous in his conclusions. With organic infusions he obtained the results of his celebrated predecessor, but he did much more—the atoms and molecules of inorganic liquids passing under his manipulation into those more "complex chemical compounds," which we dignify by calling them "living organisms."[1] As regards the public who take an interest in such things, and apparently also as regards a large portion of the medical profession, our clever countryman succeeded in restoring the subject to a state of uncertainty similar to that which followed the publication of Pouchet's volume in 1859.

It is desirable that this uncertainty should be removed from all minds, and doubly desirable on practical grounds that it should be removed from the minds of medical men. In the present article, therefore, I propose discussing this question face to face with some eminent and fair-minded member of the medical profession who, as regards spontaneous generation, entertains views adverse to mine. Such a one it would be easy to name; but it is perhaps better to rest in the impersonal. I shall therefore simply call

[1] "It is further held that bacteria or allied organisms are prone to be engendered as correlative products, coming into existence in the several fermentations, just as independently as other less complex chemical compounds."—Bastian, "Trans. of Pathological Society," vol. xxvi. 258.

my proposed co-inquirer my friend. With him at my side, I shall endeavor, to the best of my ability, so to conduct this discussion that he who runs may read and that he who reads may understand.

Let us begin at the beginning. I ask my friend to step into the laboratory of the Royal Institution, where I place before him a basin of thin turnip slices barely covered with distilled water kept at a temperature of 120° Fahr. After digesting the turnip for four or five hours we pour off the liquid, boil it, filter it, and obtain an infusion as clear as filtered drinking water. We cool the infusion, test its specific gravity, and find it to be 1006 or higher—water being 1000. A number of small clean empty flasks,



of the shape shown on the margin, are before us. One of them is slightly warmed with a spirit-lamp, and its open end is then dipped into the turnip infusion. The warmed glass is afterward chilled, the air within the flask cools, contracts, and is followed in its contraction by the infusion. Thus we get a small quantity of liquid into the flask. We now heat this liquid carefully. Steam is produced, which issues from the open neck, carrying the air of the flask along with it. After a few seconds' ebullition, the open neck is again plunged into the infusion. The steam within the flask condenses, the liquid enters to supply its place, and in this way we fill our little flask to about four-fifths of its volume. This description is typical; we may thus fill a thousand flasks with a thousand different infusions.

I now ask my friend to notice a trough made of sheet

per, with two rows of handy little Bunsen burners un-
neath it. This trough, or bath, is nearly filled with
a piece of thin plank constitutes a kind of lid for the
bath. The wood is perforated with circular apertures
e enough to allow our small flask to pass through and
nge itself in the oil, which has been heated, say, to
° Fahr. Clasped all round by the hot liquid, the in-
on in the flask rises to its boiling point, which is not
sibly over 212° Fahr. Steam issues from the open
k of the flask, and the boiling is continued for five
utes. With a pair of small brass tongs, an assistant
seizes the neck near its junction with the flask, and
ially lifts the latter out of the oil. The steam does
cease to issue, but its violence is abated. With a
nd pair of tongs held in one hand, the neck of the
k is seized close to its open end, where with the other
l a Bunsen's flame or an ordinary spirit flame is
ught under the middle of the neck. The glass red-
s, whitens, softens, and as it is gently drawn out the
k diminishes in diameter, until the canal is completely
ked up. The tongs with the fragment of severed neck
g withdrawn, the flask, with its contents diminished
evaporation, is lifted from the oil-bath perfectly sealed
netically.

Sixty such flasks filled, boiled, and sealed in the man-
described, and containing strong infusions of beef,
ton, turnip, and cucumber, are carefully packed in
dust, and transported to the Alps. Thither, to an
ation of about 7,000 feet above the sea, I invite my
nquirer to accompany me. It is the month of July,
the weather is favorable to putrefaction. We open
box at the Bel Alp, and count out fifty-four flasks,

with their liquids as clear as filtered drinking water. In six flasks, however, the infusion is found muddy. We closely examine these, and discover that every one of them has had its fragile end broken off in the transit from London. Air has entered the flasks, and the observed muddiness is the result. My colleague knows as well as I do what this means. Examined with a pocket-lens, or even with a microscope of insufficient power, nothing is seen in the muddy liquid; but regarded with a magnifying power of a thousand diameters or so, what an astonishing appearance does it present! Leeuwenhoek estimated the population of a single drop of stagnant water at 500,000,000; probably the population of a drop of our turbid infusion would be this many times multiplied. The field of the microscope is crowded with organisms, some wabbling slowly, others shooting rapidly across the microscopic field. They dart hither and thither like a rain of minute projectiles; they pirouette and spin so quickly round that the retention of the retinal impression transforms the little living rod into a twirling wheel. And yet the most celebrated naturalists tell us they are vegetables. From the rod-like shape which they so frequently assume, these organisms are called "bacteria"—a term, be it here remarked, which covers organisms of very diverse kinds.

Has this multitudinous life been spontaneously generated in these six flasks, or is it the progeny of living germinal matter carried into the flasks by the entering air? If the infusions have a self-generative power, how are the sterility and consequent clearness of the fifty-four uninjured flasks to be accounted for? My colleague may urge—and fairly urge—that the assumption of germinal matter is by no means necessary; that the air itself may

be the one thing needed to wake up the dormant infusions. We will examine this point immediately. But meanwhile I would remind him that I am working on the exact lines laid down by our most conspicuous heterogenist. He distinctly affirms that the withdrawal of the atmospheric pressure above the infusion favors the production of organisms; and he accounts for their absence in tins of preserved meat, fruit, and vegetables, by the hypothesis that fermentation *has* begun in such tins, that gases *have* been generated, the pressure of which has stifled the incipient life and stopped its further development.[1] This is the new theory of preserved meats. Had its author pierced a tin of preserved meat, fruit, or vegetable under water with the view of testing its truth, he would have found it erroneous. In well-preserved tins he would have found, not an outrush of gas, but an inrush of water. I have noticed this recently in tins which have lain perfectly good for sixty-three years in the Royal Institution. Modern tins, subjected to the same test, yielded the same result. From time to time, moreover, during the last two years, I have placed glass tubes, containing clear infusions of turnip, hay, beef, and mutton, in iron bottles, and subjected them to air-pressures varying from ten to twenty-seven atmospheres—pressures, it is needless to say, far more than sufficient to tear a preserved meat tin to shreds. After ten days these infusions were taken from their bottles rotten with putrefaction and teeming with life. Thus collapses a hypothesis which had no rational foundation, and which could never have seen the light had the slightest attempt been made to verify it.

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[1] "Beginnings of Life," vol. i. p. 418.

Our fifty-four vacuous and pellucid flasks also declare against the heterogenist. We expose them to a warm Alpine sun by day, and at night we suspend them in a warm kitchen. Four of them have been accidentally broken; but at the end of a month we find the fifty remaining ones as clear as at the commencement. There is no sign of putrefaction or of life in any of them. We divide these flasks into two groups of twenty-three and twenty-seven respectively (an accident of counting rendered the division uneven). The question now is whether the admission of air can liberate any generative energy in the infusions. Our next experiment will answer this question and something more. We carry the flasks to a hayloft, and there, with a pair of steel pliers, snip off the sealed ends of the group of three-and-twenty. Each snipping off is of course followed by an inrush of air. We now carry our twenty-seven flasks, our pliers, and a spirit-lamp, to a ledge overlooking the Aletsch glacier, about two hundred feet above the hayloft, from which ledge the mountain falls almost precipitously to the northeast for about a thousand feet. A gentle wind blows toward us from the northeast—that is, across the crests and snow-fields of the Oberland mountains. We are therefore bathed by air which must have been for a good while out of practical contact with either animal or vegetable life. I stand carefully to leeward of the flasks, for no dust or particle from my clothes or body must be blown toward them. An assistant ignites the spirit-lamp, into the flame of which I plunge the pliers, thereby destroying all attached germs or organisms. Then I snip off the sealed end of the flask. Prior to every snipping the same process is gone through, no flask being opened without the previous cleansing of the pliers by

the flame. In this way we charge our seven-and-twenty flasks with clean vivifying mountain air.

We place the fifty flasks, with their necks open, over a kitchen stove, in a temperature varying from 50° to 90° Fahr., and in three days find twenty-one out of the twenty-three flasks opened on the hayloft invaded by organisms—two only of the group remaining free from them. After three weeks' exposure to precisely the same conditions, not one of the twenty-seven flasks opened in free air had given way. No germ from the kitchen air had ascended the narrow necks, the flasks being shaped to produce this result. They are still in the Alps, as clear, I doubt not, and as free from life as they were when sent off from London.[1]

What is my colleague's conclusion from the experiment before us? Twenty-seven putrescible infusions, first in vacuo, and afterward supplied with the most invigorating air, have shown no sign of putrefaction or of life. And as to the others, I almost shrink from asking him whether the hayloft has rendered them spontaneously generative. Is not the inference here imperative that it is not the air of the loft—which is connected through a constantly open door with the general atmosphere—but something contained in the air, that has produced the effects observed? What is this something? A sunbeam entering through a chink in the roof or wall, and traversing the air of the loft, would show it to be laden with suspended dust particles. Indeed the dust is distinctly visible in the diffused daylight. Can *it* have been the origin of the observed life? If so, are we not bound by all antecedent experience to regard these fruitful particles

[1] An actual experiment made at the Bel Alp is here described.

as the germs of the life observed? The name of Baron Liebig has been constantly mixed up with these discussions. "We have," it is said, "his authority for assuming that dead decaying matter can produce fermentation." True, but with Liebig fermentation was by no means synonymous with *life*. It meant, according to him, the shaking asunder by chemical disturbance of unstable molecules. Does the life of our flasks, then, proceed from *dead* particles? If my co-inquirer should reply "Yes," then I would ask him, "What warrant does Nature offer for such an assumption? Where, amid the multitude of vital phenomena in which her operations have been clearly traced, is the slightest countenance given to the notion that the sowing of dead particles can produce a living crop?" With regard to Baron Liebig, had he studied the revelations of the microscope in relation to these questions, a mind so penetrating could never have missed the significance of the facts revealed. He, however, neglected the microscope, and fell into error—but not into error so gross as that in support of which his authority has been invoked. Were he now alive, he would, I doubt not, repudiate the use often made of his name—Liebig's view of fermentation was at least a scientific one, founded on profound conceptions of molecular instability. But this view by no means involves the notion that the planting of dead particles—"Stickstoffsplittern" as Cohn contemptuously calls them—is followed by the sprouting of infusorial life.

Let us now return to London and fix our attention on the dust of *its* air. Suppose a room in which the housemaid has just finished her work to be completely closed,

with the exception of an aperture in a shutter through which a sunbeam enters and crosses the room. The floating dust reveals the track of the light. Let a lens be placed in the aperture to condense the beam. Its parallel rays are now converged to a cone, at the apex of which the dust is raised to almost unbroken whiteness by the intensity of its illumination. Defended from all glare, the eye is peculiarly sensitive to this scattered light. The floating dust of London rooms is organic, and may be burned without leaving visible residue. The action of a spirit-lamp flame upon the floating matter has been elsewhere thus described:

In a cylindrical beam which strongly illuminated the dust of our laboratory, I placed an ignited spirit lamp. Mingling with the flame, and round its rim, were seen curious wreaths of darkness resembling an intensely black smoke. On placing the flame at some distance below the beam, the same dark masses stormed upward. They were blacker than the blackest smoke ever seen issuing from the funnel of a steamer; and their resemblance to smoke was so perfect as to prompt the conclusion that the apparently pure flame of the alcohol-lamp required but a beam of sufficient intensity to reveal its clouds of liberated carbon.

But is the blackness smoke? This question presented itself in a moment, and was thus answered: A red-hot poker was placed underneath the beam; from it the black wreaths also ascended. A large hydrogen flame, which emits no smoke, was next employed, and it also produced with augmented copiousness those whirling masses of darkness. Smoke being out of the question, what is the blackness? It is simply that of stellar space; that is to say, blackness resulting from the absence from the track of the beam of all matter competent to scatter its light. When the flame was placed below the beam, the floating matter was destroyed

situ; and the heated air, freed from this matter, rose into the beam, jostled aside the illuminated particles, and substituted for their light the darkness due to its own perfect transparency. Nothing could more forcibly illustrate the invisibility of the agent which renders all things visible. The beam crossed, unseen, the black chasm formed by the transparent air, while, at both sides of the gap, the thick-strewn particles shone out like a luminous solid under the powerful illumination.[1]

Supposing an infusion intrinsically barren, but readily susceptible of putrefaction when exposed to common air, to be brought into contact with this unilluminable air, what would be the result? It would never putrefy. It might, however, be urged that the air is spoiled by its violent calcination. Oxygen passed through a spirit-lamp flame is, it may be thought, no longer the oxygen suitable for the development and maintenance of life. We have an easy escape from this difficulty, which is based, however, upon the unproved assumption that the air has been affected by the flame. Let a condensed beam be sent through a large flask of bolthead containing common air. The track of the beam is seen within the flask—the dust revealing the light, and the light revealing the dust. Cork the flask, stuff its neck with cotton-wool, or simply turn it mouth downward and leave it undisturbed for a day or two. Examined afterward with the luminous beam, no track is visible; the light passes through the flask as through a vacuum. The floating matter has abolished itself, being now attached to the interior surface of the flask. Were it our object, as it will be subsequently, to effectually detain the dirt, we might coat that surface with

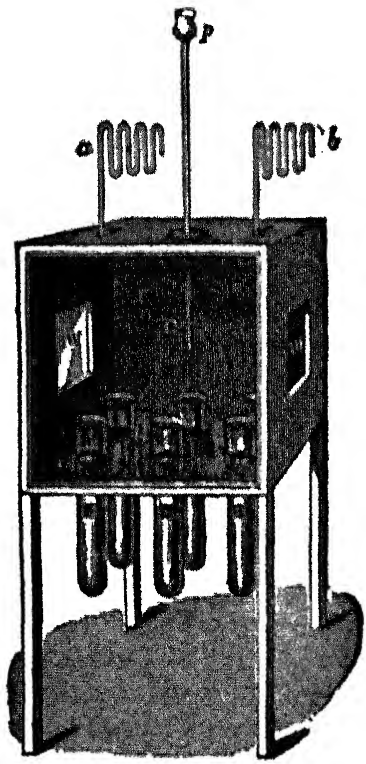
[1] See page 142, vol. I.

some sticky substance. Here, then, without "torturing" the air in any way, we have found a means of ridding it, or rather of enabling it to rid itself, of floating matter.

We have now to devise a means of testing the action of such spontaneously purified air upon putrescible infusions. Wooden chambers, or cases, are accordingly constructed, having glass fronts, side-windows, and back-doors. Through the bottoms of the chambers test-tubes pass air-tight; their open ends, for about one-fifth of the length of the tubes, being within the chambers. Provision is made for a free connection through sinuous channels between the inner and the outer air. Through such channels, though open, no dust will reach the chamber. The top of each chamber is perforated by a circular hole two inches in diameter, closed air-tight by a sheet of india-rubber. This is pierced in the middle by a pin, and through the pin-hole is pushed the shank of a long pipette ending above in a small funnel. The shank also passes through a stuffing-box of cotton-wool moistened with glycerine; so that, tightly clasped by the rubber and wool, the pipette is not likely in its motions up and down to carry any dust into the chamber. The illustration (page 330) shows a chamber, with six test-tubes, its side-windows *w w*, its pipette *p* c, and its sinuous channels *a b* which connect the air of the chamber with the outer air.

The chamber is carefully closed and permitted to remain quiet for two or three days. Examined at the beginning by a beam sent through its windows, the air is found laden with floating matter, which in three days has wholly disappeared. To prevent its ever rising again, the internal surface of the chamber was at the outset coated with glycerine. The fresh but putrescible liquid is introduced into

the six tubes in succession by means of the pipette. Permitted to remain without further precaution, every one of the tubes would putrefy and fill itself with life. The liquid has been in contact with the dust-laden air outside by which it has been infected, and the infection must be



destroyed. This is done by plunging the six tubes into a bath of heated oil and boiling the infusion. The time requisite to destroy the infection depends wholly upon its nature. Two minutes' boiling suffices to destroy some contagia, whereas two hundred minutes' boiling fails to

estroy others. After the infusion has been sterilized, e oil-bath is withdrawn, and the liquid, whose putresci-lity has been in no way affected by the boiling, is aban-oned to the air of the chamber.

With such chambers I tested, in the autumn and winter 1875–76, infusions of the most various kinds, embracing tural animal liquids, the flesh and viscera of domestic imals, game, fish, and vegetables. More than fifty ambers, each with its series of infusions, were tested, any of them repeatedly. There was no shade of uncer-inty in any of the results. In every instance we had, ithin the chamber, perfect limpidity and sweetness, which some cases lasted for more than a year—without the amber, with the same infusion, putridity and its char-teristic smells. In no instance was the least countenance nt to the notion that an infusion deprived by heat of its herent life, and placed in contact with air cleansed of s visibly suspended matter, has any power to generate e anew.

Remembering then the number and variety of the in-sions employed, and the strictness of our adherence to e rules of preparation laid down by the heterogenists emselves; remembering that we have operated upon the ry substances recommended by them as capable of fur-shing, even in untrained hands, easy and decisive proofs spontaneous generation, and that we have added to eir substances many others of our own—if this pretended nerative power were a reality, surely it must have mani-sted itself somewhere. Speaking roundly, I should say at in such closed chambers at least five hundred chances ve been given to it, but it has nowhere appeared.

The argument is now to be clinched by an experiment

which will remove every residue of doubt as to the ability of the infusions here employed to sustain life. We open the back-doors of our sealed chambers, and permit the common air with its floating particles to have access to our tubes. For three months they have remained pellucid and sweet—flesh, fish, and vegetable extracts purer than ever cook manufactured. Three days' exposure to the dusty air suffices to render them muddy, fetid, and swarming with infusorial life. The liquids are thus proved, one and all, ready for putrefaction when the contaminating agent is applied. I invite my colleague to reflect on these facts. How will he account for the absolute immunity of a liquid exposed for months in a warm room to optically pure air, and its infallible putrefaction in a few days when exposed to dust-laden air? He must, I submit, bow to the conclusion that the dust-particles are the cause of putrefactive life. And unless he accepts the hypothesis that these particles, being dead in the air, are in the liquid miraculously kindled into living things, he must conclude that the life we have observed springs from germs or organisms diffused through the atmosphere.

The experiments with hermetically sealed flasks have reached the number of 940. A sample group of 130 of them were laid before the Royal Society on January 13, 1876. They were utterly free from life, having been completely sterilized by three minutes' boiling. Special care had been taken that the temperatures to which the flasks were exposed should include those previously alleged to be efficient. The conditions laid down by the heterogenist were accurately copied, but there was no corroboration of his results. Stress was then laid on the question of warmth, thirty degrees being suddenly added to the tem-

ires with which both of us had previously worked. ing all protest against the caprice thus manifested, this new requirement also. The sealed tubes, which proved barren in the Royal Institution, were sus- ed in perforated boxes, and placed under the super- of an intelligent assistant in the Turkish Bath in yn Street. From two to six days had been allowed he generation of organisms in hermetically sealed . Mine remained in the washing-room of the bath ine days. Thermometers placed in the boxes, and off twice or three times a day, showed the tempera- to vary from a minimum of 101° to a maximum of Fahr. At the end of nine days the infusions were ear as at the beginning. They were then removed warmer position. A temperature of 115° had been ioned as particularly favorable to spontaneous genera- For fourteen days the temperature of the Turkish hovered about this point, falling once as low as 106°, ing 116° on three occasions, 118° on one, and 119° vo. The result was quite the same as that just re- ed. The higher temperatures proved perfectly incom- it to develop life.

aking the actual experiment we have made as a basis lculation, if our 940 flasks were opened on the hay- of the Bel Alp, 858 of them would become filled with nisms. The escape of the remaining 82 strengthens case, proving as it does conclusively that not in the nor in the infusions, nor in anything continuous dif- l through the air, but in *discrete particles*, suspended he air and nourished by the infusions, we are to seek cause of life. Our experiment proves these particles e in some cases so far apart on the hayloft as to per-

mit 10 per cent of our flasks to take in air without contracting contamination. A quarter of a century ago Pasteur proved the cause of "so-called spontaneous generation" to be *discontinuous.* I have already referred to his observation that 12 out of 20 flasks opened on the plains escaped infection, while 19 out of 20 flasks opened on the Mer de Glace escaped. Our own experiment at the Bel Alp is a more emphatic instance of the same kind, 90 per cent of the flasks opened in the hayloft being smitten, while not one of those opened on the free mountain ledge was attacked.

The power of the air as regards putrefactive infection is incessantly changing through natural causes, and we are able to alter it at will. Of a number of flasks opened in 1876 in the laboratory of the Royal Institution, 42 per cent were smitten, while 58 per cent escaped. In 1877 the proportion in the same laboratory was 68 per cent smitten, to 32 intact. The greater mortality, so to speak, of the infusions in 1877 was due to the presence of hay which diffused its germinal dust in the laboratory air, causing it to approximate as regards infective virulence to the air of the Alpine loft. I would ask my friend to bring his scientific penetration to bear upon all the foregoing facts. They do not prove spontaneous generation to be "impossible." My assertions, however, relate not to "possibilities," but to *proofs*, and the experiments just described do most distinctly prove the evidence on which the heterogenist relies to be written on waste paper.

My colleague will not, I am persuaded, dispute these results; but he may be disposed to urge that other able and honorable men working at the same subject have arrived at conclusions different from mine. Most freely

granted; but let me here recur to the remarks already made in speaking of the experiments of Spallanzani, to the effect that the failure of others to confirm his results by no means upsets their evidence. To fix the ideas, let us suppose that my colleague comes to the laboratory of the Royal Institution, repeats there my experiments, and obtains confirmatory results; and that he then goes to University or King's College where, operating with the same infusions, he obtains contradictory results. Will he be disposed to conclude that the self-same substance is barren in Albemarle Street and fruitful in Gower Street or the Strand? His Alpine experience has already made known to him the literally infinite differences existing between different samples of air as regards their capacity for putrefactive infection. And, possessing this knowledge, will he not substitute for the adventurous conclusion that an organic infusion is barren at one place and spontaneously generative at another, the more rational and obvious one that the atmospheres of the two localities which have had access to the infusion are infective in different degrees?

As regards workmanship, moreover, he will not fail to bear in mind that *fruitfulness* may be due to errors of manipulation, while *barrenness* involves the presumption of correct experiment. It is only the careful worker that can secure the latter, while it is open to every novice to obtain the former. Barrenness is the result at which the conscientious experimenter, whatever his theoretic convictions may be, ought to aim, omitting no pains to secure it, and resorting only when there is no escape from it to the conclusion that the life observed comes from no source which correct experiment could neutralize or avoid.

Let us again take a definite case. Supposing n league to operate with the same apparent care on 1 fusions—or rather on 100 samples of the same inf and that 50 of them prove fruitful and 50 barren. we to say that the evidence for and against hetero equally balanced? There are some who would nc say this, but who would treasure up the 50 fruitful as "positive" results, and lower the evidential va the 50 barren flasks by labelling them "negative" r This, as shown by Dr. William Roberts, is an exact sion of the true order of the terms positive and neg Not such, I trust, would be the course pursued l friend. As regards the 50 fruitful flasks he wo doubt not, repeat the experiment with redoubled ca scrutiny, and not by one repetition only, but by ma sure himself that he had not fallen into error. Such f scrutiny fully carried out would infallibly lead him conclusion that here, as in all other cases, the evide favor of spontaneous generation crumbles in the gr the competent inquirer.

The botanist knows that different seeds possess ent powers of resistance to heat.[2] Some are killed momentary exposure to the boiling temperature, whil ers withstand it for several hours. Most of our ord seeds are rapidly killed, while Pouchet made known Paris Academy of Sciences in 1866 that certain which had been transported in fleeces of wool from E

[1] See his truly philosophical remarks on this head in the "British Journal," 1876, p. 282.

[2] I am indebted to Dr. Thiselton Dyer for various illustrations of such ences. It is, however, surprising that a subject of such high scientific tance should not have been more thoroughly explored. Here the see who deal in killed seeds might be able to add to our knowledge.

"What present warrant," it has been asked, "is there for supposing that a naked, or almost naked, speck of protoplasm can withstand four, six, or eight hours' boiling?" Regarding naked specks of protoplasm I make no assertion. I know nothing about them, save as the creatures of fancy. But I do affirm, not as a "supposition," nor an "assumption," nor a "probable guess," nor as "a wild hypothesis," but as a matter of the most undoubted fact, that the spores of the hay bacillus, when thoroughly desiccated by age, have withstood the ordeal mentioned. And I further affirm that these obdurate germs, under the guidance of the knowledge that they *are* germs, can be destroyed by five minutes' boiling, or even less. This needs explanation. The finished bacterium perishes at a temperature far below that of boiling water, and it is fair to assume that the nearer the germ is to its final sensitive condition the more readily will it succumb to heat. Seeds soften before and during germination. This premised, the simple description of the following process will suffice to make its meaning understood.

An infusion infected with the most powerfully resistent germs, but otherwise protected against the floating matters of the air, is gradually raised to its boiling-point. Such germs as have reached the soft and plastic state immediately preceding their development into bacteria are thus destroyed. The infusion is then put aside in a warm room for ten or twelve hours. If for twenty-four, we might have the liquid charged with well-developed bacteria. To anticipate this, at the end of ten or twelve hours we raise the infusion a second time to the boiling temperature, which, as before, destroys all germs then approaching their point of final development. The infusion is again

ıt aside for ten or twelve hours, and the process of heat-g is repeated. We thus kill the germs *in the order of eir resistance*, and finally kill the last of them. No infu-on can withstand this process if it be repeated a suffi-ent number of times. Artichoke, cucumber, and turnip fusions, which had proved specially obstinate when in-cted with the germs of desiccated hay, were completely oken down by this method of discontinuous heating, ree minutes being found sufficient to accomplish what ree hundred minutes' continuous boiling failed to ac-mplish. I applied the method, moreover, to infusions various kinds of hay, including those most tenacious of e. Not one of them bore the ordeal. These results ere clearly foreseen before they were realized, so that e germ theory fulfils the test of every true theory, that st being the power of prevision.

When "naked or almost naked specks of protoplasm" e spoken of, the imagination is drawn upon, not the ob-ctive truth of Nature. Such words sound like the words knowledge where knowledge is really *nil*. The possi-lity of a "thin covering" is conceded by those who eak in this way. Such a covering may, however, exer-se a powerful protective influence. A thin pellicle of dia-rubber, for example, surrounding a pea keeps it rd in boiling water for a time sufficient to reduce an covered pea to a pulp. The pellicle prevents imbibition, ffusion, and the consequent disintegration. A greasy or ly surface, or even the layer of air which clings to cer-in bodies, would act to some extent in a similar way. The singular resistance of green vegetables to steriliza-on," says Dr. William Roberts, "appears to be due to me peculiarity of the surface, perhaps their smooth

glistening epidermis which prevented complete wetting of their surfaces."

I pointed out in 1876 that the process by which an atmospheric germ is wetted would be an interesting subject of investigation. A dry microscope covering-glass may be caused to float on water for a year. A sewing-needle may be similarly kept floating, though its specific gravity is nearly eight times that of water. Were it not for some specific relation between the matter of the germ and that of the liquid into which it falls, wetting would be simply impossible. Antecedent to all development there must be an interchange of matter between the germ and its environment; and this interchange must obviously depend upon the relation of the germ to its encompassing liquid. Anything that hinders this interchange retards the destruction of the germ in boiling water. In my paper, published in the "Philosophical Transactions" for 1877, I add the following remark:

It is not difficult to see that the surface of a seed or germ may be so affected by desiccation and other causes as practically to prevent contact between it and the surrounding liquid. The body of a germ, moreover, may be so indurated by time and dryness as to resist powerfully the insinuation of water between its constituent molecules. It would be difficult to cause such a germ to imbibe the moisture necessary to produce the swelling and softening which precede its destruction in a liquid of high temperature.

However this may be—whatever be the state of the surface, or of the body, of the spores of *Bacillus subtilis*, they do as a matter of certainty resist, under some circumstances, exposure for hours to the heat of boiling water. No theoretic scepticism can successfully stand in

vegetable. So long as the liquid contains living bacteria a speck of it communicated either to the clear mineral solution, or to the clear turnip infusion, produces in twenty-four hours the effect here described.

We now vary the experiment thus: Opening the back-door of another closed chamber which has contained for months the pure mineral solution and the pure turnip infusion side by side, I drop into each of them a small pinch of laboratory dust. The effect here is tardier than when the speck of putrid liquid was employed. In three days, however, after its infection with the dust, the turnip infusion is muddy, and swarming as before with bacteria. But what about the mineral solution which, in our first experiment, behaved in a manner indistinguishable from the turnip-juice? At the end of three days there is not a bacterium to be found in it. At the end of three weeks it is equally innocent of bacterial life. We may repeat the experiment with the solution and the infusion a hundred times with the same invariable result. Always in the case of the latter the sowing of the atmospheric dust yields a crop of bacteria—never in the former does the dry germinal matter kindle into active life.[1] What is the inference which the reflecting mind must draw from this experiment? Is it not as clear as day that while both liquids are able to feed the bacteria and to enable them to increase and multiply, *after they have been once fully developed*, only one of the liquids is able to develop into active bacteria the germinal dust of the air?

I invite my friend to reflect upon this conclusion; he

[1] This is the deportment of the mineral solution as described by others. My own experiments would lead me to say that the development of the bacteria, though exceedingly slow and difficult, is not impossible.

will, I think, see that there is no escape from it. He may, if he prefers, hold the opinion, which I consider erroneous, that bacteria exist in the air, not as germs but as desiccated organisms. The inference remains, that while the one liquid is able to force the passage from the inactive to the active state, the other is not.

But this is not at all the inference which has been drawn from experiments with the mineral solution. Seeing its ability to nourish bacteria when once inoculated with the living active organism, and observing that no bacteria appeared in the solution after long exposure to the air, the inference was drawn that *neither bacteria nor their germs existed in the air.* Throughout Germany the ablest literature of the subject, even that opposed to heterogeny, is infected with this error; while heterogenists at home and abroad have based upon it a triumphant demonstration of their doctrine. It is proved, they say, by the deportment of the mineral solution that neither bacteria nor their germs exist in the air; hence, if, on exposing a thoroughly sterilized turnip infusion to the air, bacteria appear, they must of necessity have been spontaneously generated. In the words of Dr. Bastian: "We can only infer that while the boiled saline solution is quite incapable of engendering bacteria, such organisms are able to arise *de novo* in the boiled organic infusion." [1]

I would ask my eminent colleague what he thinks of this reasoning now? The *datum* is—"A mineral solution exposed to common air does not develop bacteria"; the *inference* is—"Therefore if a turnip infusion similarly exposed develop bacteria, they must be spontaneously gen-

[1] "Proceedings of the Royal Society," vol. xxi. p. 130.

erated." The inference, on the face of it, is an unwarranted one. But while as matter of logic it is inconclusive, as matter of fact it is chimerical. London air is as surely charged with the germs of bacteria as London chimneys are with smoke. The inference just referred to is completely disposed of by the simple question: "Why, when your sterilized organic infusion is exposed to optically pure air, should this generation of life *de novo* utterly cease? Why should I be able to preserve my turnip-juice side by side with your saline solution for the three hundred and sixty-five days of the year, in free connection with the general atmosphere, on the sole condition that the portion of that atmosphere in contact with the juice shall be visibly free from floating dust, while three days' exposure to that dust fills it with bacteria?" Am I over-sanguine in hoping that as regards the argument here set forth he who runs may read, and he who reads may understand?

We now proceed to the calm and thorough consideration of another subject, more important if possible than the foregoing one, but like it somewhat difficult to seize by reason of the very opulence of the phraseology, logical and rhetorical, in which it has been set forth. The subject now to be considered relates to what has been called "the death-point of bacteria." Those who happen to be acquainted with the modern English literature of the question will remember how challenge after challenge has been issued to panspermatists in general, and to one or two home workers in particular, to come to close quarters on this cardinal point. It is obviously the stronghold of the English heterogenist. "Water," he says, "is boiling merrily over a fire when some luckless person upsets the ves-

sel so that the heated fluid exercises its scathing influence upon an uncovered portion of the body—hand, arm, or face. Here, at all events, there is no room for doubt. Boiling water unquestionably exercises a most pernicious and rapidly destructive effect upon the living matter of which we are composed."[1] And lest it should be supposed that it is the high organization which, in this case, renders the body susceptible to heat, he refers to the action of boiling water on the hen's egg to dissipate the notion. "The conclusion," he says, "would seem to force itself upon us that there is something intrinsically deleterious in the action of boiling water upon living matter—whether this matter be of high or of low organization."[2] Again, at another place: "It has been shown that the briefest exposure to the influence of boiling water is destructive of all living matter."[3]

The experiments already recorded plainly show that there is a marked difference between the dry bacterial matter of the air, and the wet, soft, and active bacteria of putrefying organic liquids. The one can be luxuriantly bred in the saline solution, the others refuse to be born there, while both of them are copiously developed in a sterilized turnip infusion. Inferences, as we have already seen, founded on the deportment of the one liquid cannot with the warrant of scientific logic be extended to the other. But this is exactly what the heterogenist has done, thus repeating as regards the death-point of bacteria the error into which he fell concerning the germs of the air. Let us boil our muddy mineral solution with its swarming bacteria for five minutes. In the soft succulent condition in which they exist in the solution not one of

[1] Bastian, "Evolution," p. 133. [2] Ibid., p. 135. [3] Ibid., p. 46.

them escapes destruction. The same is true of the turnip infusion if it be inoculated with the living bacteria only—the aërial dust being carefully excluded. In both cases the dead organisms sink to the bottom of the liquid, and without reinoculation no fresh organisms will arise. But the case is entirely different when we inoculate our turnip infusion with the desiccated germinal matter afloat in the air.

The "death-point" of bacteria is the maximum temperature at which they can live, or the minimum temperature at which they cease to live. If, for example, they survive a temperature of 140°, and do not survive a temperature of 150°, the death-point lies somewhere between these two temperatures. Vaccine lymph, for example, is proved by Messrs. Braidwood and Vacher to be deprived of its power of infection by brief exposure to a temperature between 140° and 150° Fahr. This may be regarded as the death-point of the lymph, or rather of the particles diffused in the lymph, which constitute the real contagium. If no time, however, be named for the application of the heat, the term "death-point" is a vague one. An infusion, for example, which will resist five hours' continuous exposure to the boiling temperature, will succumb to five days' exposure to a temperature 60° Fahr. below that of boiling. The fully developed soft bacteria of putrefying liquids are not only killed by five minutes' boiling, but by less than a single minute's boiling—indeed, they are slain at about the same temperature as the vaccine. The same is true of the plastic, active bacteria of the turnip infusion.[1]

[1] In my paper in the "Philosophical Transactions" for 1876, I pointed out and illustrated experimentally the difference, as regards rapidity of development,

But, instead of choosing a putrefying liquid for inoculation, let us prepare and employ our inoculating substance in the following simple way: Let a small wisp of hay, desiccated by age, be washed in a glass of water, and let a perfectly sterilized turnip infusion be inoculated with the washing liquid. After three hours' continuous boiling the infusion thus infected will often develop luxuriant bacterial life. Precisely the same occurs if a turnip infusion be prepared in an atmosphere well charged with desiccated hay-germs. The infusion in this case infects itself without special inoculation, and its subsequent resistance to sterilization is often very great. On the 1st of March last I purposely infected the air of our laboratory with the germinal dust of a sapless kind of hay mown in 1875. Ten groups of flasks were charged with turnip infusion prepared in the infected laboratory, and were afterward subjected to the boiling temperature for periods varying from 15 minutes to 240 minutes. Out of the ten groups only one was sterilized—that, namely, which had been boiled for four hours. Every flask of the nine groups which had been boiled for 15, 30, 45, 60, 75, 90, 105, 120, and 180 minutes respectively, bred organisms afterward. The same is true of other vegetable infusions. On the 28th of February last, for example, I boiled six flasks, containing cucumber infusion prepared in an infected atmosphere, for periods of 15, 30, 45, 60, 120, and 180 minutes. Every flask of the group subsequently developed organisms. On the same day, in the case of three

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between water-germs and air-germs; the growth from the already softened water-germs proving to be practically as rapid as from developed bacteria. This preparedness of the germ for rapid development is associated with its preparedness for rapid destruction.

flasks, the boiling was prolonged to 240, 300, and 360 minutes; and these three flasks were completely sterilized. Animal infusions, which under ordinary circumstances are rendered infallibly barren by five minutes' boiling, behave like the vegetable infusions in an atmosphere infected with hay-germs. On the 30th of March, for example, five flasks were charged with a clear infusion of beef and boiled for 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes respectively. Every one of them became subsequently crowded with organisms, and the same happened to a perfectly pellucid mutton infusion prepared at the same time. The cases are to be numbered by hundreds in which similar powers of resistance were manifested by infusions of the most diverse kinds.

In the presence of such facts I would ask my colleague whether it is necessary to dwell for a single instant on the one-sidedness of the evidence which led to the conclusion that all living matter has its life destroyed by "the briefest exposure to the influence of boiling water." An infusion proved to be barren by six months' exposure to moteless air maintained at a temperature of 90° Fahr., when inoculated with full-grown active bacteria fills itself in two days with organisms so sensitive as to be killed by a few minutes' exposure to a temperature much below that of boiling water. But the extension of this result to the desiccated germinal matter of the air is without warrant or justification. This is obvious without going beyond the argument itself. But we have gone far beyond the argument, and proved, by multiplied experiment, the alleged destruction of all living matter by the briefest exposure to the influence of boiling water to be a delusion. The whole logical edifice raised upon this basis falls therefore to the

ound; and the argument that bacteria and their germs, ng destroyed at 140°, must, if they appear after exsure to 212°, be spontaneously generated, is, I trust, enced forever.

Through the precautions, variations, and repetitions served and executed with the view of rendering its ults secure, the separate vessels employed in this inry have mounted up in two years to nearly ten thoud.

Besides the philosophic interest attaching to the probn of life's origin, which will be always immense, there the practical interests involved in the application of doctrines here discussed to surgery and medicine. e antiseptic system, at which I have already glanced, istrates the manner in which beneficent results of the vest moment follow in the wake of clear theoretic inht. Surgery was once a noble art; it is now, as well, noble science. Prior to the introduction of the antisep- system, the thoughtful surgeon could not have failed learn empirically that there was something in the air ich often defeated the most consummate operative skill. at something the antiseptic treatment destroys or rens innocuous. At King's College Mr. Lister operates l dresses while a fine shower of mixed carbolic acid l water, produced in the simplest manner, falls upon wound, the lint and gauze employed in the subsent dressing being duly saturated with the antiseptic. St. Bartholomew's Mr. Callender employs the dilute bolic acid without the spray; but, as regards the real nt aimed at—the preventing of the wound from becom- a nidus for the propagation of septic bacteria—the ctice in both hospitals is the same. Commending it-

self as it does to the scientifically trained mind, the antiseptic system has struck deep root in Germany.

Had space allowed, it would have given me pleasure to point out the present position of the "germ theory" in reference to the phenomena of infectious disease, distinguishing arguments based on analogy—which, however, are terribly strong—from those based on actual observation. I should have liked to follow up the account I have already given[1] of the truly excellent researches of a young and an unknown German physician named Koch, on splenic fever, by an account of what Pasteur has recently done with reference to the same subject. Here we have before us a living contagium of the most deadly power, which we can follow from the beginning to the end of its life cycle.[2] We find it in the blood or spleen of a smitten animal in the state, say, of short motionless rods. When these rods are placed in a nutritive liquid on the warm stage of the microscope, we soon see them lengthening into filaments which lie, in some cases, side by side, forming in others graceful loops, or becoming coiled into knots of a complexity not to be unravelled. We finally see these filaments resolving themselves into innumerable spores, each with death potentially housed within it, yet not to be distinguished microscopically from the harmless germs of *Bacillus subtilis*. The bacterium of splenic fever is called *Bacillus Anthracis*. This formidable organism was shown to me by M. Pasteur in Paris last July. His recent investigations regarding the part it plays pathologically certainly rank among the most re-

[1] "Fortnightly Review," November, 1876; see article "Fermentation."

[2] Dallinger and Drysdale had previously shown what skill and patience can accomplish, by their admirable observations on the life history of the monads.

markable labors of that remarkable man. Observer after observer had strayed and fallen in this land of pitfalls, a multitude of opposing conclusions and mutually destructive theories being the result. In association with a younger physiological colleague, M. Joubert, Pasteur struck in amid the chaos, and soon reduced it to harmony. They proved, among other things, that in cases where previous observers in France had supposed themselves to be dealing solely with splenic fever, another equally virulent factor was simultaneously active. Splenic fever was often overmastered by septicæmia, and results due solely to the latter had been frequently made the ground of pathological inferences regarding the character and cause of the former. Combining duly the two factors, all the previous irregularities disappeared, every result obtained receiving the fullest explanation. On studying the account of this masterly investigation, the words wherewith Pasteur himself feelingly alludes to the difficulties and dangers of the experimenter's art came home to me with especial force: "J'ai tant de fois éprouvé que dans cet art difficile de l'expérimentation les plus habiles bronchent à chaque pas, et que l'interprétation des faits n'est pas moins périlleuse." [1]

[1] "Comptes-Rendus," lxxxiii. p. 177.

XIV

SCIENCE AND MAN[1]

A MAGNET attracts iron; but when we analyze the effect we learn that the metal is not only attracted, but repelled, the final approach to the magnet being due to the difference of two unequal and opposing forces. Social progress is for the most part typified by this duplex or polar action. As a general rule, every advance is balanced by a partial retreat, every amelioration is associated more or less with deterioration. No great mechanical improvement, for example, is introduced for the benefit of society at large that does not bear hardly upon individuals. Science, like other things, is subject to the operation of this polar law, what is good for it under one aspect being bad for it under another.

Science demands above all things personal concentration. Its home is the study of the mathematician, the quiet laboratory of the experimenter, and the cabinet of the meditative observer of nature. Different atmospheres are required by the man of science, as such, and the man of action. Thus the facilities of social and international intercourse, the railway, the telegraph, and the post-office, which are such undoubted boons to the man of action, react to some extent injuriously on the man of science.

[1] Presidential Address, delivered before the Birmingham and Midland Institute, October 1, 1877, with additions.

Their tendency is to break up that concentrativeness which, as I have said, is an absolute necessity to the scientific investigator.

The men who have most profoundly influenced the world from the scientific side have habitually sought isolation. Faraday, at a certain period of his career, formally renounced dining out. Darwin lives apart from the bustle of the world in his quiet home in Kent. Mayer and Joule dealt with the weightiest scientific questions in unobtrusive retirement. There is, however, one motive power in the world which no man, be he a scientific student or otherwise, can afford to treat with indifference; and that is the cultivation of right relations with his fellow-men—the performance of his duty, not as an isolated individual, but as a member of society. It is duty in this aspect, overcoming alike the sense of possible danger and the desire for repose, that has placed me in your presence here to-night.

To look at his picture as a whole, a painter requires distance; and to judge of the total scientific achievement of any age, the standpoint of a succeeding age is desirable. We may, however, transport ourselves in idea into the future, and thus survey with more or less completeness the science of our time. We sometimes hear it decried, and contrasted to its disadvantage with the science of other times. I do not think that this will be the verdict of posterity. I think, on the contrary, that posterity will acknowledge that in the history of science no higher samples of intellectual conquest are recorded than those which this age has made its own. One of the most salient of these I propose, with your permission, to make the subject of our consideration during the coming hour.

It is now generally admitted that the man of to-day is the child and product of incalculable antecedent time. His physical and intellectual textures have been woven for him during his passage through phases of history and forms of existence which lead the mind back to an abysmal past. One of the qualities which he has derived from that past is the yearning to let in the light of principles on the otherwise bewildering flux of phenomena. He has been described by the German Lichtenberg as "das rastlose Ursachenthier"—the restless cause-seeking animal—in whom facts excite a kind of hunger to know the sources from which they spring. Never, I venture to say, in the history of the world has this longing been more liberally responded to, both among men of science and the general public, than during the last thirty or forty years. I say "the general public," because it is a feature of our time that the man of science no longer limits his labors to the society of his colleagues and his peers, but shares, as far as it is possible to share, with the world at large the fruits of inquiry.

The celebrated Robert Boyle regarded the universe as a machine; Mr. Carlyle prefers regarding it as a tree. He loves the image of the umbrageous Igdrasil better than that of the Strasburg clock. A machine may be defined as an organism with life and direction outside; a tree may be defined as an organism with life and direction within. In the light of these definitions, I close with the conception of Carlyle. The order and energy of the universe I hold to be inherent, and not imposed from without, the expression of fixed law and not of arbitrary will, exercised by what Carlyle would call an Almighty Clockmaker. But the two conceptions are not so much

opposed to each other after all. In one fundamental particular they at all events agree. They equally imply the interdependence and harmonious interaction of parts, and the subordination of the individual powers of the universal organism to the working of the whole.

Never were the harmony and interdependence just referred to so clearly recognized as now. Our insight regarding them is not that vague and general insight to which our fathers had attained, and which, in early times, was more frequently affirmed by the synthetic poet than by the scientific man. The interdependence of our day has become quantitative—expressible by numbers—leading, it must be added, directly into that inexorable reign of law which so many gentle people regard with dread. In the domain now under review men of science had first to work their way from darkness into twilight, and from twilight into day. There is no solution of continuity in science. It is not given to any man, however endowed, to rise spontaneously into intellectual splendor without the parentage of antecedent thought. Great discoveries grow. Here, as in other cases, we have first the seed, then the ear, then the full corn in the ear, the last member of the series implying the first. Thus, as regards the discovery of gravitation with which the name of Newton is identified, notions more or less clear concerning it had entered many minds before Newton's transcendent mathematical genius raised it to the level of a demonstration. The whole of his deductions, moreover, rested upon the inductions of Kepler. Newton shot beyond his predecessors; but his thoughts were rooted in their thoughts, and a just distribution of merit would assign to them a fair portion of the honor of discovery.

Scientific theories sometimes float like rumors in the air before they receive complete expression. The doom of a doctrine is often practically sealed, and the truth of one is often practically accepted, long prior to the demonstration of either the error or the truth. Perpetual motion was discarded before it was proved to be opposed to natural law; and, as regards the connection and interaction of natural forces, intimations of modern discoveries are strewn through the writings of Leibnitz, Boyle, Hooke, Locke and others.

Confining ourselves to recent times, Dr. Ingleby has pointed out to me some singularly sagacious remarks bearing upon this question, which were published by an anonymous writer in 1820. Roget's penetration was conspicuous in 1829. Mohr had grasped in 1837 some deep-lying truth. The writings of Faraday furnish frequent illustrations of his profound belief in the unity of nature. "I have long," he writes in 1845, "held an opinion almost amounting to conviction, in common, I believe, with other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin, or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalence of power in their action." His own researches on magneto-electricity, on electro-chemistry, and on the "magnetization of light," led him directly to this belief. At an early date Mr. Justice Grove made his mark upon this question. Colding, though starting from a metaphysical basis, grasped eventually the relation between heat and mechanical work, and sought to determine it experimentally. And here let me say that to him who has only the truth at heart, and who

is dealings with scientific history keeps his soul un-
ed by envy, hatred, or malice, personal or national,
y fresh accession to historic knowledge must be wel-
. For every new-comer of proved merit, more espe-
y if that merit should have been previously over-
ed, he makes ready room in his recognition or his
rence. But no retrospect of scientific literature has
et brought to light a claim which can sensibly affect
positions accorded to two great *Path-hewers*, as the
nans call them, whose names in relation to this sub-
are linked in indissoluble association. These names
Julius Robert Mayer and James Prescott Joule.

n his essay on "Circles" Mr. Emerson, if I remember
ly, pictured intellectual progress as rhythmic. At a
n moment knowledge is surrounded by a barrier which
ks its limit. It gradually gathers clearness and strength
by and by some thinker of exceptional power bursts
barrier and wins a wider circle, within which thought
more entrenches itself. But the internal force again
mulates, the new barrier is in its turn broken, and
mind finds itself surrounded by a still wider horizon.
, according to Emerson, knowledge spreads by inter-
ent victories instead of progressing at a uniform rate.
When Dr. Joule first proved that a weight of one
d, falling through a height of seven hundred and
nty-two feet, generated an amount of heat competent
arm a pound of water one degree Fahrenheit, and
in lifting the weight so much heat exactly disap-
ed, he broke an Emersonian "circle," releasing by the
n amount of scientific energy which rapidly overran
st domain, and embodied itself in the great doctrine
wn as the "Conservation of Energy." This doctrine

recognizes in the material universe a constant sum of power made up of items among which the most Protean fluctuations are incessantly going on. It is as if the body of Nature were alive, the thrill and interchange of its energies resembling those of an organism. The parts of the "stupendous whole" shift and change, augment and diminish, appear and disappear, while the total of which they are the parts remains quantitatively immutable. Immutable, because when change occurs it is always polar—plus accompanies minus, gain accompanies loss, no item varying in the slightest degree without an absolutely equal change of some other item in the opposite direction.

The sun warms the tropical ocean, converting a portion of its liquid into vapor, which rises in the air and is recondensed on mountain heights, returning in rivers to the ocean from which it came. Up to the point where condensation begins, an amount of heat exactly equivalent to the molecular work of vaporization and the mechanical work of lifting the vapor to the mountain-tops has disappeared from the universe. What is the gain corresponding to this loss? It will seem when mentioned to be expressed in a foreign currency. The loss is a loss of heat; the gain is a gain of distance, both as regards masses and molecules. Water which was formerly at the sea-level has been lifted to a position from which it can fall; molecules which have been locked together as a liquid are now separate as vapor which can recondense. After condensation gravity comes into effectual play, pulling the showers down upon the hills, and the rivers thus created through their gorges to the sea. Every raindrop which smites the mountain produces its definite amount of heat; every river

in its course develops heat by the clash of its cataracts and the friction of its bed. In the act of condensation, moreover, the molecular work of vaporization is accurately reversed. Compare, then, the primitive loss of solar warmth with the heat generated by the condensation of the vapor, and by the subsequent fall of the water from cloud to sea. They are mathematically equal to each other. No particle of vapor was formed and lifted without being paid for in the currency of solar heat; no particle returns as water to the sea without the exact quantitative restitution of that heat. There is nothing gratuitous in physical nature, no expenditure without equivalent gain, no gain without equivalent expenditure. With inexorable constancy the one accompanies the other, leaving no nook or crevice between them for spontaneity to mingle with the pure and necessary play of natural force. Has this uniformity of nature ever been broken? The reply is: "Not to the knowledge of science."

What has been here stated regarding heat and gravity applies to the whole of inorganic nature. Let us take an illustration from chemistry. The metal zinc may be burned in oxygen, a perfectly definite amount of heat being produced by the combustion of a given weight of the metal. But zinc may also be burned in a liquid which contains a supply of oxygen—in water, for example. It does not in this case produce flame or fire, but it does produce heat which is capable of accurate measurement. But the heat of zinc burned in water falls short of that produced in pure oxygen, the reason being that to obtain its oxygen from the water the zinc must first dislodge the hydrogen. It is in the performance of this molecular work that the missing heat is absorbed. Mix the liberated

hydrogen with oxygen and cause them to recombine; the heat developed is mathematically equal to the missing heat. Thus in pulling the oxygen and hydrogen asunder an amount of heat is consumed which is accurately restored by their reunion.

This leads up to a few remarks upon the Voltaic battery. It is not my design to dwell upon the technical features of this wonderful instrument, but simply, by means of it, to show what varying shapes a given amount of energy can assume while maintaining unvarying quantitative stability. When that form of power which we call an electric current passes through Grove's battery, zinc is consumed in acidulated water; and in the battery we are able so to arrange matters that when no current passes no zinc shall be consumed. Now the current, whatever it may be, possesses the power of generating heat outside the battery. We can fuse with it iridium, the most refractory of metals, or we can produce with it the dazzling electric light, and that at any terrestrial distance from the battery itself.

We will now, however, content ourselves with causing the current to raise a given length of platinum wire, first to a blood heat, then to redness, and finally to a white heat. The heat under these circumstances generated in the battery by the combustion of a fixed quantity of zinc is no longer constant, but it varies inversely as the heat generated outside. If the outside heat be *nil*, the inside heat is a maximum; if the external wire be raised to a blood-heat, the internal heat falls slightly short of the maximum. If the wire be rendered red-hot, the quantity of missing heat within the battery is greater, and if the external wire be rendered white-hot, the defect is greater

ll. Add together the internal and external heat pro-
.ced by the combustion of a given weight of zinc, and
u have an absolutely constant total. The heat gen-
ated without is so much lost within, the heat generated
thin is so much lost without, the polar changes already
verted to coming here conspicuously into play. Thus
a variety of ways we can distribute the items of a never-
rying sum, but even the subtle agency of the electric
rrent places no creative power in our hands.

Instead of generating external heat, we may cause the
rrent to effect chemical decomposition at a distance from
› battery. Let it, for example, decompose water into
ygen and hydrogen. The heat generated in the battery
der these circumstances by the combustion of a given
ight of zinc falls short of what is produced when there
no decomposition. How far short? The question ad-
ts of a perfectly exact answer. When the oxygen and
drogen recombine, the heat absorbed in the decomposi-
n is accurately restored, and it is exactly equal in
ount to that missing in the battery. We may, if we
e, bottle up the gases, carry in this form the heat of the
ttery to the polar regions, and liberate it there. The
ttery, in fact, is a hearth on which fuel is consumed;
t the heat of the combustion, instead of being confined
the usual manner to the hearth itself, may be first lib-
ated at the other side of the world.

And here we are able to solve an enigma which long
rplexed scientific men, and which could not be solved
til the bearing of the mechanical theory of heat upon
› phenomena of the Voltaic battery was understood.
ıe puzzle was, that a single cell could not decompose
ter. The reason is now plain enough. The solution

of an equivalent of zinc in a single cell develops not much more than half the amount of heat required to decompose an equivalent of water, and the single cell cannot cede an amount of force which it does not possess. But by forming a battery of two cells instead of one, we develop an amount of heat slightly in excess of that needed for the decomposition of the water. The two-celled battery is therefore rich enough to pay for that decomposition, and to maintain the excess referred to within its own cells.

Similar reflections apply to the thermo-electric pile, an instrument usually composed of small bars of bismuth and antimony soldered alternately together. The electric current is here evoked by warming the soldered junctions of one face of the pile. Like the Voltaic current, the thermo-electric current can heat wires, produce decomposition, magnetize iron, and deflect a magnetic needle at any distance from its origin. You will be disposed, and rightly disposed, to refer those distant manifestations of power to the heat communicated to the face of the pile, but the case is worthy of closer examination. In 1826 Thomas Seebeck discovered thermo-electricity, and six years subsequently Peltier made an observation which comes with singular felicity to our aid in determining the material used up in the formation of the thermo-electric current. He found that when a weak extraneous current was sent from antimony to bismuth the junction of the two metals was always heated, but that when the direction was from bismuth to antimony the junction was chilled. Now the current in the thermo-pile itself is always from bismuth to antimony, across the heated junction—a direction in which it cannot possibly establish itself

without consuming the heat imparted to the junction. This heat is the nutriment of the current. Thus the heat generated by the thermo-current in a distant wire is simply that originally imparted to the pile, which has been first transmuted into electricity, and then retransmuted into its first form at a distance from its origin. As water in a state of vapor passes from a boiler to a distant condenser, and there assumes its primitive form without gain or loss, so the heat communicated to the thermo-pile distils into the subtler electric current, which is, as it were, recondensed into heat in the distant platinum wire.

In my youth I thought an electro-magnetic engine which was shown to me a veritable perpetual motion—a machine, that is to say, which performed work without the expenditure of power. Let us consider the action of such a machine. Suppose it to be employed to pump water from a lower to a higher level. On examining the battery which works the engine we find that the zinc consumed does not yield its full amount of heat. The quantity of heat thus missing within is the exact thermal equivalent of the mechanical work performed without. Let the water fall again to the lower level; it is warmed by the fall. Add the heat thus produced to that generated by the friction, mechanical and magnetical, of the engine; we thus obtain the precise amount of heat missing in the battery. All the effects obtained from the machine are thus strictly paid for; this "payment for results" being, I would repeat, the inexorable method of nature.

No engine, however subtly devised, can evade this law of equivalence, or perform on its own account the smallest modicum of work. The machine distributes, but it cannot create. Is the animal body, then, to be classed

among machines? When I lift a weight, or throw a stone, or climb a mountain, or wrestle with my comrade, am I not conscious of actually creating and expending force? Let us look at the antecedents of this force. We derive the muscle and fat of our bodies from what we eat. Animal heat you know to be due to the slow combustion of this fuel. My arm is now inactive, and the ordinary slow combustion of my blood and tissue is going on. For every grain of fuel thus burned a perfectly definite amount of heat has been produced. I now contract my biceps muscle without causing it to perform external work. The combustion is quickened, and the heat is increased; this additional heat being liberated in the muscle itself. I lay hold of a 56-lb. weight, and by the contraction of my biceps lift it through the vertical space of a foot. The blood and tissue consumed during this contraction have not developed in the muscle their due amount of heat. A quantity of heat is at this moment missing in my muscle which would raise the temperature of an ounce of water somewhat more than one degree Fahrenheit. I liberate the weight: it falls to the earth, and by its collision generates the precise amount of heat missing in the muscle. My muscular heat is thus transferred from its local hearth to external space. The fuel is consumed in my body, but the heat of combustion is produced outside my body. The case is substantially the same as that of the Voltaic battery when it performs external work, or produces external heat. All this points to the conclusion that the force we employ in muscular exertion is the force of burning fuel and not of creative will. In the light of these facts the body is seen to be as incapable of generating energy without expenditure, as the solids and liquids of

he Voltaic battery. The body, in other words, falls into he category of machines.

We can do with the body all that we have already lone with the battery—heat platinum wires, decompose water, magnetize iron, and deflect a magnetic needle. The combustion of muscle may be made to produce all hese effects, as the combustion of zinc may be caused to produce them. By turning the handle of a magneto-electric machine a coil of wire may be caused to rotate between the poles of a magnet. As long as the two ends of he coil are unconnected we have simply to overcome the ordinary inertia and friction of the machine in turning the handle. But the moment the two ends of the coil are united by a thin platinum wire a sudden addition of labor s thrown upon the turning arm. When the necessary abor is expended, its equivalent immediately appears. The platinum wire glows. You can readily maintain it at a white heat, or even fuse it. This is a very remarkable result. From the muscles of the arm, with a temperature of 100°, we extract the temperature of molten platinum, which is nearly four thousand degrees. The miracle here is the reverse of that of the burning bush mentioned n Exodus. There the bush burned, but was not consumed: here the body is consumed, but does not burn. The similarity of the action with that of the Voltaic battery when it heats an external wire is too obvious to need pointing out. When the machine is used to decompose water, the heat of the muscle, like that of the battery, is consumed in molecular work, being fully restored when he gases recombine. As before, also, the transmuted heat of the muscles may be bottled up, carried to the polar regions, and there restored to its pristine form.

The matter of the human body is the same as that of the world around us; and here we find the forces of the human body identical with those of inorganic nature. Just as little as the Voltaic battery is the animal body a creator of force. It is an apparatus exquisite and effectual beyond all others in transforming and distributing the energy with which it is supplied, but it possesses no creative power. Compared with the notions previously entertained regarding the play of "vital force" this is a great result. The problem of vital dynamics has been described by a competent authority as "the grandest of all." I subscribe to this opinion, and honor correspondingly the man who first successfully grappled with the problem. He was no pope, in the sense of being infallible, but he was a man of genius whose work will be held in honor as long as science endures. I have already named him in connection with our illustrious countryman, Dr. Joule. Other eminent men took up this subject subsequently and independently, but all that has been done hitherto enhances instead of diminishing the merits of Dr. Mayer.

Consider the vigor of his reasoning. "Beyond the power of generating internal heat, the animal organism can generate heat external to itself. A blacksmith by hammering can warm a nail, and a savage by friction can heat wood to its point of ignition. Unless, then, we abandon the physiological axiom that the animal body cannot create heat out of nothing, we are driven to the conclusion that *it is the total heat, within and without, that ought to be regarded as the real calorific effect of the oxidation within the body.*" Mayer, however, not only states the principle, but illustrates numerically the transfer of muscular heat to external space. A bowler who imparts a

ocity of 30 feet to an 8-lb. ball consumes in the act $\frac{1}{10}$ grain of carbon. The heat of the muscle is here dis-uted over the track of the ball, being developed there mechanical friction. A man weighing 150 lbs. con-nes in lifting his own body to a height of 8 feet the t of a grain of carbon. Jumping from this height the t is restored. The consumption of 2 oz. 4 drs. 20 grs. carbon would place the same man on the summit of a intain 10,000 feet high. In descending the mountain amount of heat equal to that produced by the combus- of the foregoing amount of carbon is restored. The scles of a laborer whose weight is 150 lbs. weigh 64 When dried they are reduced to 15 lbs. Were the lation corresponding to a day-laborer's ordinary work rted on the muscles alone, they would be wholly con-ned in 80 days. Were the oxidation necessary to sus- the heart's action concentrated on the heart itself, it ld be consumed in 8 days. And if we confine our ntion to the two ventricles, their action would con-ne the associated muscular tissue in 3½ days. With a ness and precision of which this is but a sample did yer, between 1842 and 1845, deal with the great ques- of vital dynamics.

In direct opposition, moreover, to the foremost scien- authorities of that day, with Liebig at their head, solitary Heilbronn worker was led by his calculations naintain that the muscles, in the main, played the part machinery, converting the fat, which had been previ-ly considered a mere heat-producer, into the motive ver of the organism. Mayer's prevision has been jus-ed by events, for the scientific world is now upon his e.

We place, then, food in our stomachs as so much combustible matter. It is first dissolved by purely chemical processes, and the nutritive fluid is poured into the blood. Here it comes into contact with atmospheric oxygen admitted by the lungs. It unites with the oxygen as wood or coal might unite with it in a furnace. The matter-products of the union, if I may use the term, are the same in both cases; viz., carbonic acid and water. The force-products are also the same—heat within the body, or heat and work outside the body. Thus far every action of the organism belongs to the domain either of physics or of chemistry. But you saw me contract the muscle of my arm. What enabled me to do so? Was it or was it not the direct action of my will? The answer is, the action of the will is mediate, not direct. Over and above the muscles the human organism is provided with long whitish filaments of medullary matter, which issue from the spinal column, being connected by it on the one side with the brain, and on the other side losing themselves in the muscles. Those filaments or cords are the nerves, which you know are divided into two kinds, sensor and motor, or, if you like the terms better, afferent and efferent nerves. The former carry impressions from the external world to the brain; the latter convey the behests of the brain to the muscles. Here, as elsewhere, we find ourselves aided by the sagacity of Mayer, who was the first clearly to formulate the part played by the nerves in the organism. Mayer saw that neither nerves nor brain, nor both together, possessed the energy necessary to animal motion; but he also saw that the nerve could lift a latch and open a door, by which floods of energy are let loose. "As an engineer," he says with admirable lucid-

ity, "by the motion of his finger in opening a valve or loosening a detent can liberate an amount of mechanical energy almost infinite compared with its exciting cause; so the nerves, acting on the muscles, can unlock an amount of power out of all proportion to the work done by the nerves themselves." The nerves, according to Mayer, pull the trigger, but the gunpowder which they ignite is stored in the muscles. This is the view now universally entertained.

The quickness of thought has passed into a proverb, and the notion that any measurable time elapsed between the infliction of a wound and the feeling of the injury would have been rejected as preposterous thirty years ago. Nervous impressions, notwithstanding the results of Haller, were thought to be transmitted, if not instantaneously, at all events with the rapidity of electricity. Hence, when Helmholtz, in 1851, affirmed, as the result of experiment, nervous transmission to be a comparatively sluggish process, very few believed him. His experiments may now be made in the lecture-room. Sound in air moves at the rate of 1,100 feet a second; sound in water moves at the rate of 5,000 feet a second; light in ether moves at the rate of 186,000 miles a second, and electricity in free wires moves probably at the same rate. But the nerves transmit their messages at the rate of only 70 feet a second, a progress which in these quick times might well be regarded as inordinately slow.

Your townsman, Mr. Gore, has produced by electrolysis a kind of antimony which exhibits an action strikingly analogous to that of nervous propagation. A rod of this antimony is in such a molecular condition that when you scratch or heat one end of the rod, the disturbance

propagates itself before your eyes to the other end, the onward march of the disturbance being announced by the development of heat and fumes along the line of propagation. In some such way the molecules of the nerves are successively overthrown; and if Mr. Gore could only devise some means of winding up his exhausted antimony, as the nutritive blood winds up exhausted nerves, the comparison would be complete. The subject may be summed up, as Du Bois-Reymond has summed it up, by reference to the case of a whale struck by a harpoon in the tail. If the animal were 70 feet long, a second would elapse before the disturbance could reach the brain. But the impression after its arrival has to diffuse itself and throw the brain into the molecular condition necessary to consciousness. Then, and not till then, the command to the tail to defend itself is shot through the motor nerves. Another second must elapse before the command can reach the tail, so that more than two seconds transpire between the infliction of the wound and the muscular response of the part wounded. The interval required for the kindling of consciousness would probably more than suffice for the destruction of the brain by lightning, or even by a rifle-bullet. Before the organ can arrange itself it may, therefore, be destroyed, and in such a case we may safely conclude that death is painless.

The experiences of common life supply us with copious instances of the liberation of vast stores of muscular power by an infinitesimal "priming" of the muscles by the nerves. We all know the effect produced on a "nervous" organization by a slight sound which causes affright. An aërial wave, the energy of which would not reach a

minute fraction of that necessary to raise the thousandth of a grain through the thousandth of an inch, can throw the whole human frame into a powerful mechanical spasm, followed by violent respiration and palpitation. The eye, of course, may be appealed to as well as the ear. Of this the lamented Lange gives the following vivid illustration:

A merchant sits complacently in his easy-chair, not knowing whether smoking, sleeping, newspaper reading, or the digestion of food occupies the largest portion of his personality. A servant enters the room with a telegram bearing the words, "Antwerp, etc. . . . Jonas and Co. have failed." "Tell James to harness the horses!" The servant flies. Up starts the merchant, wide awake; makes a dozen paces through the room, descends to the counting-house, dictates letters, and forwards despatches. He jumps into his carriage, the horses snort, and their driver is immediately at the bank, on the Bourse, and among his commercial friends. Before an hour has elapsed he is again at home, where he throws himself once more into his easy-chair with a deep-drawn sigh, "Thank God I am protected against the worst, and now for further reflection."

This complex mass of action, emotional, intellectual, and mechanical, is evoked by the impact upon the retina of the infinitesimal waves of light coming from a few pencil marks on a bit of paper. We have, as Lange says, terror, hope, sensation, calculation, possible ruin, and victory compressed into a moment. What caused the merchant to spring out of his chair? The contraction of his muscles. What made his muscles contract? An impulse of the nerves, which lifted the proper latch and liberated the muscular power. Whence this impulse? From the

centre of the nervous system. But how did it originate there? This is the critical question, to which some will reply that it had its origin in the human soul.

The aim and effort of science is to explain the unknown in terms of the known. Explanation, therefore, is conditioned by knowledge. You have probably heard the story of the German peasant, who, in early railway days, was taken to see the performance of a locomotive. He had never known carriages to be moved except by animal power. Every explanation outside of this conception lay beyond his experience, and could not be invoked. After long reflection therefore, and seeing no possible escape from the conclusion, he exclaimed confidently to his companion, "Es müssen doch Pferde darin sein"—There must be horses inside. Amusing as this locomotive theory may seem, it illustrates a deep-lying truth.

With reference to our present question, some may be disposed to press upon me such considerations as these: Your motor nerves are so many speaking-tubes, through which messages are sent from the man to the world; and your sensor nerves are so many conduits through which the whispers of the world are sent back to the man. But you have not told us where *is* the man. Who or what is it that sends and receives those messages through the bodily organism? Do not the phenomena point to the existence of a self within the self, which acts through the body as through a skilfully constructed instrument? You picture the muscles as hearkening to the commands sent through the motor nerves, and you picture the sensor nerves as the vehicles of incoming intelligence; are you not bound to supplement this mechanism by the assumption of an entity which uses it? In other words, are you

forced by your own exposition into the hypothesis of
eo human soul?

This is fair reasoning now, and, at a certain stage of the
ld's knowledge, it might well have been deemed con-
sive. Adequate reflection, however, shows that instead
introducing light into our minds, this hypothesis con-
red scientifically increases our darkness. You do not
this case explain the unknown in terms of the known,
ch, as stated above, is the method of science, but you
lain the unknown in terms of the more unknown.
to mentally visualize this soul as an entity distinct
n the body, and the difficulty immediately appears.
n the side of science all that we are warranted in stat-
is that the terror, hope, sensation, and calculation of
go's merchant are psychical phenomena produced by,
ssociated with, the molecular processes set up by waves
ight in a previously prepared brain.

When facts present themselves let us dare to face them,
let the man of science equally dare to confess igno-
e where it prevails. What then is the causal connec-
, if any, between the objective and subjective—be-
en molecular motions and states of consciousness? My
wer is: I do not see the connection, nor have I as yet
anybody who does. It is no explanation to say that
objective and subjective effects are two sides of one
the same phenomenon. Why should the phenomenon
e two sides? This is the very core of the difficulty.
re are plenty of molecular motions which do not ex-
t this two-sidedness. Does water think or feel when
ns into frost-ferns upon a window-pane? If not, why
uld the molecular motion of the brain be yoked to this
sterious companion—consciousness? We can form a

coherent picture of the physical processes—the stirring of the brain, the thrilling of the nerves, the discharging of the muscles, and all the subsequent mechanical motions of the organism. But we can present to our minds no picture of the process whereby consciousness emerges, either as a necessary link or as an accidental by-product of this series of actions. Yet it certainly does emerge—the prick of a pin suffices to prove that molecular motion can produce consciousness. The reverse process of the production of motion by consciousness is equally unpresentable to the mind. We are here, in fact, upon the boundary line of the intellect, where the ordinary canons of science fail to extricate us from our difficulties. If we are true to these canons, we must deny to subjective phenomena all influence on physical processes. Observation proves that they interact, but in passing from one to the other, we meet a blank which mechanical deduction is unable to fill. Frankly stated, we have here to deal with facts almost as difficult to seize mentally as the idea of a soul. And if you are content to make your "soul" a poetic rendering of a phenomenon which refuses the yoke of ordinary physical laws, I, for one, would not object to this exercise of ideality. Amid all our speculative uncertainty, however, there is one practical point as clear as the day; namely, that the brightness and the usefulness of life, as well as its darkness and disaster, depend to a great extent upon our own use or abuse of this miraculous organ.

Accustomed as I am to harsh language, I am quite prepared to hear my "poetic rendering" branded as a "falsehood" and a "fib." The vituperation is unmerited, for poetry or ideality, and untruth are assuredly very dif-

ferent things. The one may vivify, while the other kills. When St. John extends the notion of a soul to "souls washed in the blood of Christ" does he "fib"? Indeed, if the appeal to ideality is censurable, Christ himself ought not to have escaped censure. Nor did he escape it. "How can this man give us his flesh to eat?" expressed the sceptical flouting of unpoetic natures. Such are still among us. Cardinal Manning would doubtless tell any Protestant who rejects the doctrine of transubstantiation that he "fibs" away the plain words of his Saviour when he reduces "the Body of the Lord" in the sacrament to a mere figure of speech.

Though misuse may render it grotesque or insincere, the idealization of ancient conceptions, when done consciously and aboveboard, has, in my opinion, an important future. We are not radically different from our historic ancestors, and any feeling which affected them profoundly requires only appropriate clothing to affect us. The world will not lightly relinquish its heritage of poetic feeling, and metaphysics will be welcomed when it abandons its pretensions to scientific discovery and consents to be ranked as a kind of poetry. "A good symbol," says Emerson, "is a missionary to persuade thousands. The Vedas, the Edda, the Koran, are each remembered by its happiest figure. There is no more welcome gift to men than a new symbol. They assimilate themselves to it, deal with it in all ways, and it will last a hundred years. Then comes a new genius and brings another." Our ideas of God and the soul are obviously subject to this symbolic mutation. They are not now what they were a century ago. They will not be a century hence what they are now. Such ideas constitute a

kind of central energy in the human mind, capable, like the energy of the physical universe, of assuming various shapes and undergoing various transformations. They baffle and elude the theological mechanic who would carve them to dogmatic forms. They offer themselves freely to the poet who understands his vocation, and whose function is, or ought to be, to find "local habitation" for thoughts woven into our subjective life, but which refuse to be mechanically defined.

We now stand face to face with the final problem. It is this: Are the brain, and the moral and intellectual processes known to be associated with the brain—and, as far as our experience goes, indissolubly associated—subject to the laws which we find paramount in physical nature? Is the will of man, in other words, free, or are it and nature equally "bound fast in fate"? From this latter conclusion, after he had established it to the entire satisfaction of his understanding, the great German thinker Fichte recoiled. You will find the record of this struggle between head and heart in his book, entitled "Die Bestimmung des Menschen"—The Vocation of Man.[1] Fichte was determined at all hazards to maintain his freedom, but the price he paid for it indicates the difficulty of the task. To escape from the iron necessity seen everywhere reigning in physical nature, he turned defiantly round upon nature and law, and affirmed both of them to be the products of his own mind. He was not going to be the slave of a thing which he had himself created. There is a good deal to be said in favor of this view, but few of

[1] Translated by Dr. William Smith of Edinburgh: Trübner, 1873.

transcendentalism whereby Fichte melted his chains.

Why do some regard this notion of necessity with terror, while others do not fear it at all? Has not Carlyle somewhere said that a belief in destiny is the bias of all earnest minds? "It is not Nature," says Fichte, "it is Freedom itself, by which the greatest and most terrible disorders incident to our race are produced. Man is the cruelest enemy of man." But the question of moral responsibility here emerges, and it is the possible loosening of this responsibility that so many of us dread. The notion of necessity certainly failed to frighten Bishop Butler. He thought it untrue—even absurd—but he did not fear its practical consequences. He showed, on the contrary, in the "Analogy," that as far as human conduct is concerned, the two theories of free-will and necessity would come to the same in the end.

What is meant by free-will? Does it imply the power of producing events without antecedents?—of starting, as it were, upon a creative tour of occurrences without any impulse from within or from without? Let us consider the point. If there be absolutely or relatively no reason why a tree should fall, it will not fall; and if there be absolutely or relatively no reason why a man should act, he will not act. It is true that the united voice of this assembly could not persuade me that I have not, at this moment, the power to lift my arm if I wished to do so. Within this range the conscious freedom of my will cannot be questioned. But what about the origin of the "wish"? Are we, or are we not, complete masters of the circumstances which create our wishes, motives, and tendencies to action? Adequate reflection will, I think,

prove that we are not. What, for example, have I had to do with the generation and development of that which some will consider my total being, and others a most potent factor of my total being—the living, speaking organism which now addresses you? As stated at the beginning of this discourse, my physical and intellectual textures were woven *for* me, not *by* me. Processes in the conduct or regulation of which I had no share have made me what I am. Here, surely, if anywhere, we are as clay in the hands of the potter. It is the greatest of delusions to suppose that we come into this world as sheets of white paper on which the age can write anything it likes, making us good or bad, noble or mean, as the age pleases. The age can stunt, promote, or pervert pre-existent capacities, but it cannot create them. The worthy Robert Owen, who saw in external circumstances the great molders of human character, was obliged to supplement his doctrine by making the man himself one of the circumstances. It is as fatal as it is cowardly to blink facts because they are not to our taste. How many disorders, ghostly and bodily, are transmitted to us by inheritance? In our courts of law, whenever it is a question whether a crime has been committed under the influence of insanity, the best guidance the judge and jury can have is derived from the parental antecedents of the accused. If among these insanity be exhibited in any marked degree, the presumption in the prisoner's favor is enormously enhanced, because the experience of life has taught both judge and jury that insanity is frequently transmitted from parent to child.

I met, some years ago, in a railway carriage the governor of one of our largest prisons. He was evidently an

servant and reflective man, possessed of wide experi-
ce gathered in various parts of the world and a thor-
gh student of the duties of his vocation. He told me
t the prisoners in his charge might be divided into
ee distinct classes. The first class consisted of persons
o ought never to have been in prison. External acci-
nt, and not internal taint, had brought them within the
sp of the law, and what had happened to them might
ppen to most of us. They were essentially men of
nd moral stamina, though wearing the prison garb.
en came the largest class, formed of individuals pos-
sing no strong bias, moral or immoral, plastic to the
ch of circumstances, which could mold them into either
od or evil members of society. Thirdly came a class—
ppily not a large one—whom no kindness could con-
ate and no discipline tame. They were sent into this
rld labelled "incorrigible," wickedness being stamped,
it were, upon their organizations. It was an unpleas-
truth, but as a truth it ought to be faced. For such
minals the prison over which he ruled was certainly not
proper place. If confined at all, their prison should
on a desert island, where the deadly contagion of their
ample could not taint the moral air. But the sea itself
was disposed to regard as a cheap and appropriate sub-
ute for the island. It seemed to him evident that the
te would benefit if prisoners of the first class were lib-
ted; prisoners of the second class educated; and prison-
of the third class put compendiously under water.

It is not, however, from the observation of individuals
t the argument against "free-will," as commonly under-
od, derives its principal force. It is, as already hinted,
efinitely strengthened when extended to the race. Most

of you have been forced to listen to the outcries and denunciations which rang discordant through the land for some years after the publication of Mr. Darwin's "Origin of Species." Well, the world—even the clerical world—has for the most part settled down in the belief that Mr. Darwin's book simply reflects the truth of nature: that we who are now "foremost in the files of time" have come to the front through almost endless stages of promotion from lower to higher forms of life.

If to any one of us were given the privilege of looking back through the eons across which life has crept toward its present outcome, his vision, according to Darwin, would ultimately reach a point when the progenitors of this assembly could not be called human. From that humble society, through the interaction of its members and the storing up of their best qualities, a better one emerged; from this again a better still; until at length, by the integration of infinitesimals through ages of amelioration, we came to be what we are to-day. We of this generation had no conscious share in the production of this grand and beneficent result. Any and every generation which preceded us had just as little share. The favored organisms whose garnered excellence constitutes our present store owed their advantages, first, to what we in our ignorance are obliged to call "accidental variation"; and, secondly, to a law of heredity in the passing of which our suffrages were not collected. With characteristic felicity and precision Mr. Matthew Arnold lifts this question into the free air of poetry, but not out of the atmosphere of truth, when he ascribes the process of amelioration to "a power not ourselves which makes for righteousness." If, then, our organisms, with all their tendencies and capaci-

are given to us without our being consulted; and if, capable of acting within certain limits in accordance our wishes, we are not masters of the circumstances hich motives and wishes originate; if, finally, our es and wishes determine our actions—in what sense hese actions be said to be the result of free-will?

ere, again, we are confronted with the question of responsibility, which, as it has been much talked ely, it is desirable to meet. With the view of reg the fear of our falling back into the condition of ape and tiger," so sedulously excited by certain s, I propose to grapple with this question in its form, and in the most uncompromising way. "If," he robber, the ravisher, or the murderer, "I act be I must act, what right have you to hold me respon- for my deeds?" The reply is, "The right of society otect itself against aggressive and injurious forces, er they be bond or free, forces of nature or forces n." "Then," retorts the criminal, "you punish me hat I cannot help." "Let it be granted," says so- "but had you known that the treadmill or the gal- was certainly in store for you, you might have d.' Let us reason the matter fully and frankly out. nay entertain no malice or hatred against you; it is h that with a view to our own safety and purifica- ve are determined that you and such as you shall njoy liberty of evil action in our midst. You, who behaved as a wild beast, we claim the right to cage l as we should a wild beast. The public safety is a of more importance than the very limited chance ur moral renovation, while the knowledge that you

have been hanged by the neck may furnish to others about to do as you have done the precise motive which will hold them back. If your act be such as to invoke a minor penalty, then not only others, but yourself, may profit by the punishment which we inflict. On the homely principle that 'a burned child dreads the fire,' it will make you think twice before venturing on a repetition of your crime. Observe, finally, the consistency of our conduct. You offend, you say, because you cannot help offending, to the public detriment. We punish, is our reply, because we cannot help punishing, for the public good. Practically, then, as Bishop Butler predicted, we act as the world acted when it supposed the evil deeds of its criminals to be the products of free-will."[1]

"What," I have heard it argued, "is the use of preaching about duty, if a man's predetermined position in the moral world renders him incapable of profiting by advice?" Who knows that he is incapable? The preacher's last word is a factor in the man's conduct, and it may be a most important factor, unlocking moral energies which might otherwise remain imprisoned and unused. If the preacher thoroughly feel that words of enlightenment, courage, and admonition enter into the list of forces employed by Nature herself for man's amelioration, since she gifted man with speech, he will suffer no paralysis to fall upon his tongue. Dung the fig-tree hopefully, and not until its barrenness has been demonstrated beyond a doubt let the sentence go forth, "Cut it down, why cumbereth it the ground?"

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[1] An eminent Church dignitary describes all this, not unkindly, as "truculent logic." I think it worthy of his Grace's graver consideration.

I remember when a youth in the town of Halifax, some -and-thirty years ago, attending a lecture given by a ng man to a small but select audience. The aspect of lecturer was earnest and practical, and his voice soon ted attention. He spoke of duty, defining it as a debt d, and there was a kindling vigor in his words which t have strengthened the sense of duty in the minds of se who heard him. No speculations regarding the free- of the will could alter the fact that the words of that ng man did me good. His name was George Dawson. also spoke, if you will allow me to allude to it, of a al subject much discussed at the time—the Chartist ject of "levelling." Suppose, he says, two men to be al at night, and that one rises at six, while the other ps till nine next morning, what becomes of your level-? And in so speaking he made himself the mouth-e of Nature, which, as we have seen, secures advance, by the reduction of all to a common level, but by the ouragement and conservation of what is best.

It may be urged that, in dealing as above with my othetical criminal, I am assuming a state of things ught about by the influence of religions which include dogmas of theology and the belief in free-will—a state, nely, in which a moral majority control and keep in an immoral minority. The heart of man is deceitful ve all things, and desperately wicked. Withdraw, then, theologic sanctions, including the belief in free-will, the condition of the race will be typified by the sam- of individual wickedness which have been above ad-ed. We shall all, that is, become robbers, and rav-ers, and murderers. From much that has been written late it would seem that this astounding inference finds

house-room in many minds. Possibly, the people who hold such views might be able to illustrate them by individual instances.

> The fear of hell's a hangman's whip,
> To keep the wretch in order.

Remove the fear, and the wretch, following his natural instinct, may become disorderly; but I refuse to accept him as a sample of humanity. "Let us eat and drink, for to-morrow we die" is by no means the ethical consequence of a rejection of dogma. To many of you the name of George Jacob Holyoake is doubtless familiar, and you are probably aware that at no man in England has the term "atheist" been more frequently pelted. There are, moreover, really few who have more completely liberated themselves from theologic notions. Among working-class politicians Mr. Holyoake is a leader. Does he exhort his followers to "Eat and drink, for to-morrow we die"? Not so. In the August number of the "Nineteenth Century" you will find these words from his pen: "The gospel of dirt is bad enough, but the gospel of mere material comfort is much worse." He contemptuously calls the Comtist championship of the working man, "the championship of the trencher." He would place "the leanest liberty which brought with it the dignity and power of self-help" higher than "any prospect of a full plate without it." Such is the moral doctrine taught by this "atheistic" leader; and no Christian, I apprehend, need be ashamed of it.

Most heartily do I recognize and admire the spiritual radiance, if I may use the term, shed by religion on the minds and lives of many personally known to me. At the

time I cannot but observe how signally, as regards production of anything beautiful, religion fails in other . Its professor and defender is sometimes at bottom awler and a clown. These differences depend upon ary distinctions of character which religion does not ve. It may comfort some to know that there are g us many whom the gladiators of the pulpit would "atheists" and "materialists," whose lives, neverthe- as tested by any accessible standard of morality, would ast more than favorably with the lives of those who to stamp them with this offensive brand. When I 'offensive," I refer simply to the intention of those use such terms, and not because atheism or material- when compared with many of the notions ventilated e columns of religious newspapers, has any particular siveness for me. If I wished to find men who are ulous in their adherence to engagements, whose words heir bond, and to whom moral shiftiness of any kind bjectively unknown; if I wanted a loving father, a ful husband, an honorable neighbor, and a just citi- -I should seek him, and find him among the band of eists" to which I refer. I have known some of the pronounced among them not only in life, but in —seen them approaching with open eyes the inex- e goal, with no dread of a "hangman's whip," with ope of a heavenly crown, and still as mindful of duties, and as faithful in the discharge of them, their eternal future depended upon their latest s.

letters addressed to myself, and in utterances ad- ed to the public, Faraday is often referred to as a le of the association of religious faith with moral ele-

vation. I was locally intimate with him for fourteen or fifteen years of my life, and had thus occasion to observe how nearly his character approached what might, without extravagance, be called perfection. He was strong but gentle, impetuous but self restrained; a sweet and lofty courtesy marked his dealings with men and women; and though he sprang from the body of the people, a nature so fine might well have been distilled from the flower of antecedent chivalry. Not only in its broader sense was the Christian religion necessary to Faraday's spiritual peace, but in what many would call the narrow sense held by those described by Faraday himself as "a very small and despised sect of Christians, known, if known at all, as Sandemanians," it constituted the light and comfort of his days.

Were our experience confined to such cases, it would furnish an irresistible argument in favor of the association of dogmatic religion with moral purity and grace. But, as already intimated, our experience is not thus confined. In further illustration of this point, we may compare with Faraday a philosopher of equal magnitude, whose character, including gentleness and strength, candor and simplicity, intellectual power and moral elevation, singularly resembles that of the great Sandemanian, but who has neither shared the theologic views nor the religious emotions which formed so dominant a factor in Faraday's life. I allude to Mr. Charles Darwin, the Abraham of scientific men—a searcher as obedient to the command of truth as was the patriarch to the command of God. I cannot therefore, as so many desire, look upon Faraday's religious belief as the exclusive source of qualities shared so conspicuously by one uninfluenced by that belief. To a deeper

ue belonging to human nature in its purer forms I am osed to refer the excellence of both.

Superstition may be defined as constructive religion ch has grown incongruous with intelligence. We may it, with Fichte, "that superstition has unquestionably strained its subjects to abandon many pernicious prac- s and to adopt many useful ones"; the real loss accom- ying its decay at the present day has been thus clearly d by the same philosopher: "In so far as these lamen- ons do not proceed from the priests themselves—whose f at the loss of their dominion over the human mind can well understand—but from the politicians, the le matter resolves itself into this, that government has eby become more difficult and expensive. The judge spared the exercise of his own sagacity and penetra- when, by threats of relentless damnation, he could pel the accused to make confession. The evil spirit herly performed without reward services for which in r times judges and policemen have to be paid."

No man ever felt the need of a high and ennobling gion more thoroughly than this powerful and fervid her, who, by the way, did not escape the brand of heist." But Fichte asserted emphatically the power sufficiency of morality in its own sphere. "Let us sider," he says, "the highest which man can possess the absence of religion—I mean pure morality. The al man obeys the law of duty in his breast absolutely, use it is a law unto him; and he does whatever re- s itself to him as his duty simply because it is duty. not the impudent assertion be repeated that such an dience, without regard for consequences, and without re for consequences, is in itself impossible and op-

posed to human nature." So much for Fichte. Faraday was equally distinct. "I have no intention," he says, "of substituting anything for religion, but I wish to take that part of human nature which is independent of it. Morality, philosophy, commerce, the various institutions and habits of society, are independent of religion and may exist without it." These were the words of his youth, but they expressed his latest convictions. I would add that the muse of Tennyson never reached a higher strain than when it embodied the sentiment of duty in Œnone:

> And, because right is right, to follow right
> Were wisdom in the scorn of consequence.

Not in the way assumed by our dogmatic teachers has the morality of human nature been built up. The power which has molded us thus far has worked with stern tools upon a very rigid stuff. What it has done cannot be so readily undone; and it has endowed us with moral constitutions which take pleasure in the noble, the beautiful, and the true, just as surely as it has endowed us with sentient organisms, which find aloes bitter and sugar sweet.

That power did not work with delusions, nor will it stay its hand when such are removed. Facts, rather than dogmas, have been its ministers—hunger and thirst, heat and cold, pleasure and pain, fervor, sympathy, aspiration, shame, pride, love, hate, terror, awe—such were the forces whose interaction and adjustment throughout an immeasurable past wove the triplex web of man's physical, intellectual, and moral nature, and such are the forces that will be effectual to the end.

You may retort that even on my own showing "the

wer which makes for righteousness" *has* dealt in delu-ns; for it cannot be denied that the beliefs of religion, luding the dogmas of theology and the freedom of the ll, have had some effect in molding the moral world. anted; but I do not think that this goes to the root of matter. Are you quite sure that those beliefs and gmas are primary, and not derived?—that they are not *products*, instead of being the *creators*, of man's moral ture? I think it is in one of the Latter-Day Pamphlets at Carlyle corrects a reasoner, who deduced the nobility man from a belief in heaven, by telling him that he ts the cart before the horse, the real truth being that belief in heaven is derived from the nobility of man. e bird's instinct to weave its nest is referred to by nerson as typical of the force which built cathedrals, nples, and pyramids:

> Knowest thou what wove yon woodbird's nest
> Of leaves and feathers from her breast,
> Or how the fish outbuilt its shell,
> Painting with morn each annual cell?
> Such and so grew these holy piles
> While love and terror laid the tiles;
> Earth proudly wears the Parthenon
> As the best gem upon her zone;
> And Morning opes with haste her lids
> To gaze upon the Pyramids;
> O'er England's abbeys bends the sky
> As on its friends with kindred eye;
> For out of Thought's interior sphere
> These wonders rose to upper air,
> And nature gladly gave them place,
> Adopted them into her race,
> And granted them an equal date
> With Andes and with Ararat.

Surely, many utterances which have been accepted as descriptions ought to be interpreted as aspirations, or as having their roots in aspiration instead of in objective knowledge. Does the song of the herald angels, "Glory to God in the highest, and on earth peace, goodwill toward men," express the exaltation and the yearning of a human soul? or does it describe an optical and acoustical fact—a visible host and an audible song? If the former, the exaltation and the yearning are man's imperishable possession—a ferment long confined to individuals, but which may by and by become the leaven of the race. If the latter, then belief in the entire transaction is wrecked by non fulfilment. Look to the East at the present moment as a comment on the promise of peace on earth and goodwill toward men. That promise is a dream ruined by the experience of eighteen centuries, and in that ruin is involved the claim of the "heavenly host" to prophetic vision. But though the mechanical theory proves untenable, the immortal song and the feelings it expresses are still ours, to be incorporated, let us hope, in purer and less shadowy forms in the poetry, philosophy, and practice of the future.

Thus, following the lead of physical science, we are brought without solution of continuity into the presence of problems which, as usually classified, lie entirely outside the domain of physics. To these problems thoughtful and penetrative minds are now applying those methods of research which in physical science have proved their truth by their fruits. There is on all hands a growing repugnance to invoke the supernatural in accounting for the phenomena of human life; and the thoughtful minds just referred to, finding no trace of evidence in favor of any other origin, are driven to seek in the interaction of social

es the genesis and development of man's moral nature. hey succeed in their search—and I think they are sure ucceed social duty will be raised to a higher level of ificance and the deepening sense of social duty will, it o be hoped, lessen, if not obliterate, the strifes and rtburnings which now beset and disfigure our social Toward this great end it behooves us one and all vork; and devoutly wishing its consummation, I have honor, ladies and gentlemen, to bid you a friendly well.

XV

PROFESSOR VIRCHOW AND EVOLUTION

THIS world of ours has, on the whole, been an inclement region for the growth of natural truth; but it may be that the plant is all the hardier for the bendings and buffetings it has undergone. The torturing of a shrub, within certain limits, strengthens it. Through the struggles and passions of the brute, man reaches his estate; through savagery and barbarism his civilization; and through illusion and persecution his knowledge of nature, including that of his own frame. The bias toward natural truth must have been strong to have withstood and overcome the opposing forces. Feeling appeared in the world before Knowledge; and thoughts, conceptions, and creeds, founded on emotion, had, before the dawn of science, taken root in man. Such thoughts, conceptions, and creeds must have met a deep and general want; otherwise their growth could not have been so luxuriant, nor their abiding power so strong. This general need—this hunger for the ideal and wonderful—led eventually to the differentiation of a caste, whose vocation it was to cultivate the mystery of life and its surroundings, and to give shape, name, and habitation to the emotions which that mystery aroused. Even the savage lived, not by bread alone, but in a mental world peopled with forms answering to his capacities and needs. As time advanced

other words, as the savage opened out into civilized —those forms were purified and ennobled until they lly emerged in the mythology and art of Greece:

> Where still the magic robe of Poesy
> Wound itself lovingly around the Truth.[1]

As poets, the priesthood would have been justified, r deities, celestial and otherwise, with all their retinue appliances, being more or less legitimate symbols and onifications of the aspects of nature and the phases of human soul. The priests, however, or those among n who were mechanics, and not poets, claimed objec- validity for their conceptions, and tried to base upon rnal evidence that which sprang from the innermost l and nature of man. It is against this objective ren- ng of the emotions—this thrusting into the region of and positive knowledge of conceptions essentially l and poetic—that science, consciously or uncon- usly, wages war. Religious feeling is as much a ver- as any other part of human consciousness; and against n its subjective side, the waves of science beat in vain. when, manipulated by the constructive imagination, ed with imperfect or inaccurate historic data, and led by misapplied logic, this feeling makes claims ch traverse our knowledge of nature, science, as in bound, stands as a hostile power in its path. It is nst the mythologic scenery, if I may use the term, er than against the life and substance of religion, that nce enters her protest. Sooner or later among think- people, that scenery will be taken for what it is worth

[1] "Da der Dichtung zauberische Hülle
Sich noch lieblich um die Wahrheit wand."—*Schiller.*

—as an effort on the part of man to bring the mystery of life and nature within the range of his capacities; as a temporary and essentially fluxional rendering in terms of knowledge of that which transcends all knowledge, and admits only of ideal approach.

The signs of the times, I think, point in this direction. It is, for example, the obvious aim of Mr. Matthew Arnold to protect, amid the wreck of dogma, the poetic basis of religion. And it is to be remembered that under the circumstances poetry may be the purest accessible truth. In other influential quarters a similar spirit is at work. In a remarkable article published by Professor Knight of St. Andrews in the September number of the "Nineteenth Century," amid other free utterances, we have this one: "If matter is not eternal, its first emergence into being is a miracle beside which all others dwindle into absolute insignificance. But, as has often been pointed out, the process is unthinkable; the sudden apocalypse of a material world out of blank nonentity cannot be imagined;[1] its emergence into order out of chaos when 'without form and void' of life, *is merely a poetic rendering of the doctrine of its slow evolution.*" These are all bold words to be spoken before the moral philosophy class of a Scotch university, while those I have underlined show a remarkable freedom of dealing with the sacred text. They repeat in terser language what I ventured to utter four years ago regarding the Book of Genesis. "Profoundly interesting and indeed pathetic to me are those attempts of the opening mind of man to appease its hunger for a Cause.

[1] Professor Knight will have to reckon with the English Marriage Service, one of whose Collects begins thus: "O God, who by thy mighty power hast made all things of nothing."

the Book of Genesis has no voice in scientific ques-s. *It is a poem, not a scientific treatise.* In the former ct it is forever beautiful; in the latter it has been, it will continue to be, purely obstructive and hurt-' My agreement with Professor Knight extends still ier. "Does the vital," he asks, "proceed by a still ›ter development from the non-vital? Or was it cre-by a fiat of volition? Or"—and here he emphasizes question—"*has it always existed in some form or other n eternal constituent of the universe?* I do not see," eplies, "how we can escape from the last alternative." h the whole force of my conviction I say, Nor do I, gh our modes of regarding the "eternal constituent" not be the same.

When matter was defined by Descartes, he deliberately uded the idea of force or motion from its attributes from his definition. *Extension* only was taken into unt. And, inasmuch as the impotence of matter to ›rate motion was assumed, its observed motions were rred to an external cause. God, resident outside of ter, gave the impulse. In this connection the argu-t in Young's "Night Thoughts" will occur to most ers:

> Who Motion foreign to the smallest grain
> Shot through vast masses of enormous weight?
> Who bid brute Matter's restive lump assume
> Such various forms, and gave it wings to fly?

inst this notion of Descartes the great deist John To-, whose ashes lie unmarked in Putney Churchyard, uously contended. He affirmed motion to be an in-nt attribute of matter—that no portion of matter was est, and that even the most quiescent solids were ani-

mated by a motion of their ultimate particles. The success of his contention, according to the learned and laborious Dr. Berthold,[1] entitles Toland to be regarded as the founder of that *monistic* doctrine which is now so rapidly spreading.

It seems to me that the idea of vitality entertained in our day by Professor Knight closely resembles the idea of motion entertained by his opponents in Toland's day. Motion was then virtually asserted to be a thing *sui generis*, distinct from matter, and incapable of being generated out of matter. Hence the obvious inference when matter was observed to move. It was the vehicle of an energy not its own—the repository of forces impressed on it from without—the purely passive recipient of the shock of the Divine. The logical form continues, but the subject-matter is changed. "The evolution of nature," says Professor Knight, "may be a fact; a daily and hourly apocalypse. But we have no evidence of the non-vital passing into the vital. Spontaneous generation is, as yet, an imaginative guess, unverified by scientific tests. And matter is not itself alive. Vitality, whether seen in a single cell of protoplasm or in the human brain, is a thing *sui generis*, distinct from matter, and incapable of being generated out of matter." It may be, however, that, in process of time, vitality will follow the example of motion, and, after the necessary antecedent wrangling, take its place among the attributes of that "universal mother" who has been so often misdefined.

That "matter is not itself alive" Professor Knight seems to regard as an axiomatic truth. Let us place in

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[1] "John Toland und der Monismus der Gegenwart," Heidelberg, Carl Winter.

ntrast with this the notion entertained by the philos-
her Ueberweg, one of the subtlest heads that Germany
s produced. "What occurs in the brain," says Ueber-
g, "would, in my opinion, not be possible, if the proc-
which here appears in its greatest concentration did
t obtain generally, only in a vastly diminished degree.
ke a pair of mice and a cask of flour. By copious
urishment the animals increase and multiply, and in the
ne proportion sensations and feelings augment. The
antity of these latter possessed by the first pair is not
nply diffused among their descendants, for in that case
last must feel more feebly than the first. The sensa-
ns and feelings must necessarily be referred back to
flour, where they exist, weak and pale it is true, and
concentrated as they are in the brain."[1] We may
be able to taste or smell alcohol in a tub of fermented
rries, but by distillation we obtain from them concen-
ted Kirschwasser. Hence Ueberweg's comparison of
brain to a still, which concentrates the sensation and
ling, pre-existing, but diluted in the food.

"Definitions," says Mr. Holyoake,[2] "grow as the hori-
of experience expands. They are not inventions, but
criptions of the state of a question. No man sees all
ough a discovery at once." Thus Descartes's notion
matter, and his explanation of motion, would be put
le as trivial by a physiologist or a crystallographer of
present day. They are not descriptions of the state
the question. And yet a desire sometimes shows itself
distinguished quarters to bind us down to conceptions

Letter to Lange: "Geschichte des Materialismus," zweite Aufl., vol. ii.
21.

"Nineteenth Century" September, 1878.

which passed muster in the infancy of knowledge, but which are wholly incompatible with our present enlightenment. Mr. Martineau, I think, errs when he seeks to hold me to views enunciated by "Democritus and the mathematicians." That definitions should change as knowledge advances is in accordance both with sound sense and scientific practice. When, for example, the undulatory theory was started, it was not imagined that the vibrations of light could be transverse to the direction of propagation. The example of sound was at hand, which was a case of longitudinal vibration. Now the substitution of transverse for longitudinal vibrations in the case of light involved a radical change of conception as to the mechanical properties of the luminiferous medium. But though this change went so far as to fill space with a substance, possessing the properties of a solid, rather than those of a gas, the change was accepted, because the newly discovered facts imperatively demanded it. Following Mr. Martineau's example, the opponent of the undulatory theory might effectually twit the holder of it on his change of front. "This ether of yours," he might say, "alters its style with every change of service. Starting as a beggar, with scarce a rag of 'property' to cover its bones, it turns up as a prince when large undertakings are wanted. You had some show of reason when, with the case of sound before you, you assumed your ether to be a gas in the last extremity of attenuation. But now that new service is rendered necessary by new facts, you drop the beggar's rags, and accomplish an undertaking, great and princely enough in all conscience; for it implies that not only planets of enormous weight, but comets with hardly any weight at all, fly through your hypothet-

solid without perceptible loss of motion." This would
d very cogent, but it would be very vain. Equally
, in my opinion, is Mr. Martineau's contention that
are not justified in modifying, in accordance with ad-
ing knowledge, our notions of matter.

Before parting from Professor Knight, let me commend
courage as well as his insight. We have heard much
ate of the peril to morality involved in the decay of
gious belief. What Mr. Knight says under this head
worthy of all respect and attention. "I admit," he
es, "that were it proved that the moral faculty was
ved as well as developed, its present decisions would
be invalidated. The child of experience has a father
se teachings are grave, peremptory, and august; and
arthborn rule may be as stringent as any derived from
lestial source. It does not even follow that a belief in
material origin of spiritual existence, accompanied by
rresponding decay of belief in immortality, must *nec-
rily* lead to a relaxation of the moral fibre of the race.
certain that it has often done so.[1] But it is equally
ain that there have been individuals, and great histor-
communities, in which the absence of the latter belief
neither weakened moral earnestness nor prevented de-
onal fervor." I have elsewhere stated that some of
best men of my acquaintance—men lofty in thought
beneficent in act—belong to a class who assiduously
the belief referred to alone. They derive from it
her stimulus nor inspiration, while—I say it with re-
—were I in quest of persons who, in regard to the

Is this really certain? Instead of standing in the relation of cause and
, may not the "decay" and "relaxation" be merely coexistent, both, per-
flowing from common historic antecedents?'

finer endowments of human character, are to be ranked with the unendowed, I should find some characteristic samples among the noisier defenders of the orthodox belief. These, however, are but "hand specimens" on both sides; the wider data referred to by Professor Knight constitute, therefore, a welcome corroboration of my experience. Again, my excellent critic, Professor Blackie, describes Buddha as being "a great deal more than a prophet; a rare, exceptional, and altogether transcendental incarnation of moral perfection."[1] And yet, "what Buddha preached was a gospel of pure human ethics, divorced not only from Brahma and the Brahminic Trinity, but even from the existence of God."[2] These civilized and gallant voices from the North contrast pleasantly with the barbarous whoops which sometimes come to us along the same meridian.

Looking backward from my present standpoint over the earnest past, a boyhood fond of play and physical action, but averse to school work, lies before me. The aversion did not arise from intellectual apathy or want of appetite for knowledge, but simply from the fact that my earliest teachers lacked the power of imparting vitality to what they taught. Athwart all play and amusement, however, a thread of seriousness ran through my character; and many a sleepless night of my childhood has been passed, fretted by the question "Who made God?" I was well versed in Scripture; for I loved the Bible, and was prompted by that love to commit large portions of it to memory. Later on I became adroit in turning my Script-

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[1] "Natural History of Atheism," p. 136. [2] Ibid., p. 126.

l knowledge against the Church of Rome, but the char-
eristic doctrines of that Church marked only for a time
limits of inquiry. The eternal Sonship of Christ, for
ample, as enunciated in the Athanasian Creed, perplexed
The resurrection of the body was also a thorn in my
nd, and here I remember that a passage in Blair's
rave" gave me momentary rest.

> Sure the same power
> That rear'd the piece at first and took it down
> Can reassemble the loose, scatter'd parts
> And put them as they were.

e conclusion seemed for the moment entirely fair, but
h further thought my difficulties came back to me. I
l seen cows and sheep browsing upon churchyard grass,
ich sprang from the decaying mould of dead men. The
h of these animals was undoubtedly a modification of
nan flesh, and the persons who fed upon them were as
loubtedly, in part, a more remote modification of the
ne substance. I figured the self-same molecules as be-
ging first to one body and afterward to a different one,
l I asked myself how two bodies so related could pos-
ly arrange their claims at the day of resurrection. The
ttered parts of each were to be reassembled and set as
y were. But if handed over to the one, how could
y possibly enter into the composition of the other?
nipotence itself, I concluded, could not reconcile the
tradiction. Thus the plank which Blair's mechanical
ory of the resurrection brought momentarily into sight,
appeared, and I was again cast abroad on the waste
an of speculation.
At the same time I could by no means get rid of the

idea that the aspects of nature and the consciousness of man implied the operation of a power altogether beyond my grasp—an energy the thought of which raised the temperature of the mind, though it refused to accept shape, personal or otherwise, from the intellect. Perhaps the able critics of the "Saturday Review" are justified in speaking as they sometimes do of Mr. Carlyle. They owe him nothing, and have a right to announce the fact in their own way. I, however, owe him a great deal, and am also in honor bound to acknowledge the debt. Few, perhaps, who are privileged to come into contact with that illustrious man have shown him a sturdier front than I have, or in discussing modern science have more frequently withstood him. But I could see that his contention at bottom always was that the human soul has claims and yearnings which physical science cannot satisfy. England to come will assuredly thank him for his affirmation of the ethical and ideal side of human nature. Be this as it may, at the period now reached in my story the feeling referred to was indefinitely strengthened, my whole life being at the same time rendered more earnest, resolute, and laborious by the writings of Carlyle. Others also ministered to this result. Emerson kindled me, while Fichte powerfully stirred my moral pulse.[1] In this relation I cared little for political theories or philosophic systems, but a great deal for the propagated life and strength of pure and powerful minds. In my later school days, under a clever teacher, some knowledge of mathe-

[1] The reader will find in the Seventeenth Lecture of Fichte's course on the "Characteristics of the Present Age" a sample of the vital power of this philosopher.

and physics had been picked up: my stock of was, however, scanty, and I resolved to augment ut it was really with the view of learning whether matics and physics could help me in other spheres, than with the desire of acquiring distinction in science, that I ventured, in 1848, to break the uity of my life, and devote the meagre funds then disposal to the study of science in Germany.

t science soon fascinated me on its own account. rry it duly and honestly out, moral qualities were ntly invoked. There was no room allowed for in-ty—no room even for carelessness. The edifice of had been raised by men who had unswervingly ed the truth as it is in nature; and in doing so ften sacrificed interests which are usually potent in orld.

nong these rationalistic men of Germany I found ntiousness in work as much insisted on as it could nong theologians. And why, since they had not wards or penalties of the theologian to offer to their es? Because they assumed, and were justified in ng, that those whom they addressed had that within which would respond to their appeal. If Germany ever change for something less noble the simple ness and fidelity to duty, which in those days char-ed her teachers, and through them her sons gener-t will not be because of rationalism. Such a de-Germany might coexist with the most rampant lism without their standing to each other in the n of cause and effect.

first really laborious investigation, conducted jointly ny friend Professor Knoblauch, landed me in a re-

gion which harmonized with my speculative tastes. It was essentially an inquiry in molecular physics, having reference to the curious, and then perplexing, phenomena exhibited by crystals when freely suspended in the magnetic field. I here lived amid the most complex operations of magnetism in its twofold aspect of an attractive and a repellent force. Iron was attracted by a magnet, bismuth was repelled, and the crystals operated on ranged themselves under these two heads. Faraday and Plücker had worked assiduously at the subject, and had invoked the aid of new forces to account for the phenomena. It was soon, however, found that the displacement in a crystal of an atom of the iron class by an atom of the bismuth class, involving no change of crystalline form, produced a complete reversal of the phenomena. The lines through the crystal which were in the one case drawn toward the poles of the magnet, were driven, in the other case, from these poles. By such instances and the reasoning which they suggested, magne-crystallic action was proved to be due, not to the operation of new forces, but to the modification of the old ones by molecular arrangement. Whether diamagnetism, like magnetism, was a polar force, was in those days a subject of the most lively contention. It was finally proved to be so; and the most complicated cases of magne-crystallic action were immediately shown to be simple mechanical consequences of the principle of diamagnetic polarity.

These early researches, which occupied in all five years of my life, and throughout which the molecular architecture of crystals was an incessant subject of mental contemplation, gave a tinge and bias to my subsequent scientific thought, and their influence is easily

l in my subsequent inquiries. For example, during years of labor on the subject of radiation, heat and were handled throughout by me, not as ends, but as uments by the aid of which the mind might per-:o lay hold upon the ultimate particles of matter.

ientific progress depends mainly upon two factors incessantly interact—the strengthening of the mind ercise, and the illumination of phenomena by knowl-There seems no limit to the insight regarding phys-rocesses which this interaction carries in its train. gh such insight we are enabled to enter and explore ubsensible world into which all natural phenomena their roots, and from which they derive nutrition. we are enabled to place before the mind's eye and atomic motions which lie far beyond the range senses, and to apply to them reasoning as stringent t applied by the mechanician to the motions and col-of sensible masses. But once committed to such ptions, there is a risk of being irresistibly led be-the bounds of inorganic nature. Even in those early of scientific growth, I found myself more and more lled to regard not only crystals, but organic struct-the body of man inclusive, as cases of molecular cture, infinitely more complex, it is true, than those rganic nature, but reducible, in the long run, to the mechanical laws. In ancient journals I find recorded rings and speculations relating to these subjects, and pts made, by reference to magnetic and crystalline mena, to present some satisfactory image to the mind way in which plants and animals are built up. Per-I may be excused for noting a sample of these early ations, already possibly known to a few of my read-

ers, but which here finds a more suitable place than that which it formerly occupied.

Sitting, in the summer of 1855, with my friend Dr. Debus under the shadow of a massive elm on the bank of a river in Normandy, the current of our thoughts and conversation was substantially this: We regarded the tree above us. In opposition to gravity its molecules had ascended, diverged into branches, and budded into innumerable leaves. What caused them to do so—a power external to themselves, or an inherent force? Science rejects the outside builder; let us, therefore, consider from the other point of view the experience of the present year. A low temperature had kept back for weeks the life of the vegetable world. But at length the sun gained power—or, rather, the cloud-screen which our atmosphere had drawn between him and us was removed—and life immediately kindled under his warmth. But what is life, and how can solar light and heat thus affect it? Near our elm was a silver birch, with its leaves rapidly quivering in the morning air. We had here motion, but not the motion of life. Each leaf moved as a mass under the influence of an outside force, while the motion of life was inherent and molecular. How are we to figure this molecular motion—the forces which it implies, and the results which flow from them? Suppose the leaves to be shaken from the tree and enabled to attract and repel each other. To fix the ideas, suppose the point of each leaf to repel all the other points and to attract the roots, and the root of each leaf to repel all other roots, but to attract the points. The leaves would then resemble an assemblage of little magnets abandoned freely to the interaction of their

wn forces. In obedience to these they would arrange iemselves, and finally assume positions of rest, forming coherent mass. Let us suppose the breeze, which now uses them to quiver, to disturb the assumed equilibrium. s often as disturbed there would be a constant effort on ie part of the leaves to re-establish it; and in making is effort the mass of leaves would pass through different iapes and forms. If other leaves, moreover, were at ind endowed with similar forces, the attraction would tend to them—a growth of the mass of leaves being the nsequence.

We have strong reason for assuming that the ultimate rticles of matter—the atoms and molecules of which it made up—are endowed with forces coarsely typified by ose here ascribed to the leaves. The phenomena of crysllization, lead, of necessity, to this conception of molecur polarity. Under the operation of such forces the molelles of a seed, like our fallen leaves in the first instance, ke up positions from which they would never move if idisturbed by an external impulse. But solar light and eat, which come to us as waves through space, are the eat agents of molecular disturbance. On the inert molelles of seed and soil these waves impinge, disturbing the omic equilibrium, which there is an immediate effort to store. The effort, incessantly defeated—for the waves ntinue to pour in—is incessantly renewed; in the moeular struggle matter is gathered from the soil and from e atmosphere, and built, in obedience to the forces which iide the molecules, into the special form of the tree. In general way, therefore, the life of the tree might be deied as an unceasing effort to restore a disturbed equiorium. In the building of crystals Nature makes her

first structural effort; we have here the earliest groping of the so-called "vital force," and the manifestations of this force in plants and animals, though, as already stated, indefinitely more complex, are to be regarded of the same mechanical quality as those concerned in the building of the crystal.

Consider the cycle of operations by which the seed produces the plant, the plant the flower, the flower again the seed, the causal line, returning with the fidelity of a planetary orbit to its original point of departure. Who or what planned this molecular rhythm? We do not know—science fails even to inform us whether it was ever "planned" at all. Yonder butterfly has a spot of orange on its wing: and if we look at a drawing made a century ago, of one of the ancestors of that butterfly, we probably find the self-same spot upon the wing. For a century the molecules have described their cycles. Butterflies have been begotten, have been born, and have died; still we find the molecular architecture unchanged. Who or what determined this persistency of recurrence? We do not know; but we stand within our intellectual range when we say that there is probably nothing in that wing which may not yet find its Newton to prove that the principles involved in its construction are qualitatively the same as those brought into play in the formation of the solar system. We may even take a step further, and affirm that the brain of man—the organ of his reason—without which he can neither think nor feel, is also an assemblage of molecules, acting and reacting according to law. Here, however, the methods pursued in mechanical science come to an end; and if asked to deduce from the physical interaction of the brain molecules the least of the phenomena

of sensation or thought, I acknowledge my helplessness. The association of both with the matter of the brain may be as certain as the association of light with the rising of the sun. But whereas in the latter case we have unbroken mechanical connection between the sun and our organs, in the former case logical continuity disappears. Between molecular mechanics and consciousness is interposed a fissure over which the ladder of physical reasoning is incompetent to carry us. We must, therefore, accept the observed association as an empirical fact, without being able to bring it under the yoke of *a priori* deduction.

Such were the ponderings which ran habitually through my mind in the days of my scientific youth. They illustrate two things—a determination to push physical considerations to their utmost legitimate limit; and an acknowledgment that physical considerations do not lead to the final explanation of all that we feel and know. This acknowledgment, be it said in passing, was by no means made with the view of providing room for the play of considerations other than physical. The same intellectual duality, if I may use the phrase, manifests itself in the following extract from an article entitled "Physics and Metaphysics," published in the "Saturday Review" for August 4, 1860:

"The philosophy of the future will assuredly take more account than that of the past of the dependence of thought and feeling on physical processes; and it may be that the qualities of the mind will be studied through organic combinations as we now study the character of a force through the affections of ordinary matter. We believe that every

thought and every feeling has its definite mechanical correlative—that it is accompanied by a certain breaking up and remarshalling of the atoms of the brain. This latter process is purely physical; and were the faculties we now possess sufficiently expanded, without the creation of any new faculty, it would doubtless be within the range of our augmented powers to infer from the molecular state of the brain the character of the thought acting on it, and, conversely, to infer from the thought the exact molecular condition of the brain. We do not say—and this, as will be seen, is all-important—that the inference here referred to would be an *à priori* one. But by observing, with the faculties we assume, the state of the brain and the associated mental affections, both might be so tabulated side by side that, if one were given, a mere reference to the table would declare the other. Our present powers, it is true, shrivel into nothingness when brought to bear on such a problem, but it is because of its complexity and our limits that this is the case. The *quality* of the problem and of our powers are, we believe, so related, that a mere expansion of the latter would enable them to cope with the former. Why, then, in scientific speculation should we turn our eyes exclusively to the past? May it not be that a time is coming—ages no doubt distant, but still advancing—when the dwellers upon this fair earth, starting from the gross human brain of to-day as a rudiment, may be able to apply to these mighty questions faculties of commensurate extent? Given the requi-

no absolute breach of continuity between us and our
er brothers yet to come.

'We have guarded ourselves against saying that the
rring of thought from material combinations and ar-
gements would be an inference *à priori*. The infer-
meant would be the same in kind as that which the
rvation of the effects of food and drink upon the mind
ld enable us to make, differing only from the latter
he degree of analytical insight which we suppose
ined. Given the masses and distances of the planets,
an infer the perturbations consequent on their mutual
ctions. Given the nature of a disturbance in water,
or ether—knowing the physical qualities of the me-
n we can infer how its particles will be affected. In
his we deal with physical laws. The mind runs with
ainty along the line of thought which connects the
nomena, and from beginning to end there is no break
e chain. But when we endeavor to pass by a similar
ess from the phenomena of physics to those of thought,
neet a problem which transcends any conceivable ex-
sion of the powers which we now possess. We may
k over the subject again and again, but it eludes all
lectual presentation. We stand at length face to face
the Incomprehensible. The territory of physics is
, but it has its limits from which we look with vacant
into the region beyond. Let us follow matter to its
ost bounds, let us claim it in all its forms—even in
muscles, blood, and brain of man himself—as ours to
riment with and to speculate upon. Casting the term
l force' from our vocabulary, let us reduce, if we can,
visible phenomena of life to mechanical attractions
repulsions. Having thus exhausted physics, and

reached its very rim, a mighty Mystery still looms beyond us. We have, in fact, made no step toward its solution. And thus it will ever loom, compelling the philosophies of successive ages to confess that

> "'We are such stuff
> As dreams are made of, and our little life
> Is rounded by a sleep.'"

In my work on "Heat," published in 1863, and republished many times since, I employ the precise language thus extracted from the "Saturday Review."

The distinction is here clearly brought out which I had resolved at all hazards to draw—that, namely, between what men know or might know, and what they could never hope to know. Impart simple magnifying power to our present vision, and the atomic motions of the brain itself might be brought into view. Compare these motions with the corresponding states of consciousness, and an empirical nexus might be established; but "we try to soar in a vacuum when we endeavor to pass by logical deduction from the one to the other." Among these brain-effects a new product appears which defies mechanical treatment. We cannot deduce motion from consciousness or consciousness from motion as we deduce one motion from another. Nevertheless observation is open to us, and by it relations may be established which are at least as valid as those of the deductive reason. The difficulty may really lie in the attempt to convert a datum into an inference—an ultimate fact into a product of logic. My desire for the moment, however, is not to theorize, but to let facts speak in reply to accusation.

The most "materialistic" speculation for which I was

sponsible, prior to the "Belfast Address," is embodied n the following extract from a brief article written as far ack as 1865: "Supposing the molecules of the human ody, instead of replacing others, and thus renewing a re-existing form, to be gathered first-hand from nature, nd placed in the exact relative positions which they ocupy in the body. Supposing them to have the same rces and distribution of forces, the same motions and istribution of motions—would this organized concourse molecules stand before us as a sentient, thinking being? here seems no valid reason to assume that it would not. r supposing a planet carved from the sun, set spinning ound an axis, and sent revolving round the sun at a disnce equal to that of our earth, would one consequence the refrigeration of the mass be the development of rganic forms? I lean to the affirmative." This is plain eaking, but it is without "dogmatism." An opinion is pressed, a belief, a *leaning*—not an established "docine."

The burden of my writings in this connection is as uch a recognition of the weakness of science as an asseron of its strength. In 1867, I told the working men of undee that while making the largest demand for freedom investigation; while considering science to be alike powful as an instrument of intellectual culture, and as a inistrant to the material wants of men; if asked whether ience has solved, or is likely in our day to solve, "the oblem of the universe," I must shake my head in doubt. compare the mind of man to a musical instrument with certain range of notes, beyond which in both directions ists infinite silence. The phenomena of matter and rce come within our intellectual range; but behind, and

above, and around us the real mystery of the universe lies unsolved, and, as far as we are concerned, is incapable of solution.

While refreshing my mind on these old themes I appear to myself as a person possessing one idea, which so overmasters him that he is never weary of repeating it. That idea is the polar conception of the grandeur and the littleness of man—the vastness of his range in some respects and directions, and his powerlessness to take a single step in others. In 1868, before the Mathematical and Physical Section of the British Association, then assembled at Norwich, I repeat the same well worn note:

"In thus affirming the growth of the human body to be mechanical, and thought as exercised by us to have its correlative in the physics of the brain, the position of the 'materialist,' as far as that position is tenable, is stated. I think the materialist will be able finally to maintain this position against all attacks, but I do not think he can pass beyond it. The problem of the connection of body and soul is as insoluble in its modern form as it was in the pre-scientific ages. Phosphorus is a constituent of the human brain, and a trenchant German writer has exclaimed, 'Ohne Phosphor kein gedanke!' That may or may not be the case; but, even if we knew it to be the case, the knowledge would not lighten our darkness. On both sides of the zone here assigned to the materialist he is equally helpless. If you ask him whence is this 'matter' of which we have been discoursing—who or what divided it into molecules, and impressed upon them this necessity of running into organic forms—he has no answer. Science is also mute in regard to such questions. But if the materialist is confounded and science is rendered

, who else is prepared with an answer? Let us
our heads and acknowledge our ignorance, priest
philosopher, one and all."

ne roll of echoes which succeeded the Lecture deliv-
by Professor Virchow at Munich on September 22,
was long and loud. The "Times" published a
full translation of the lecture, and it was eagerly
ented on in other journals. Glances from it to an
ess delivered by me before the Midland Institute in
utumn of 1877, and published in this volume, were
frequent. Professor Virchow was held up to me in
quarters as a model of philosophic caution, who by
asonableness reproved my rashness, and by his depth
ved my shallowness. With true theologic courtesy I
edulously emptied, not only of the "principles of
ific thought," but of "common modesty" and "com-
sense." And though I am indebted to Professor
rd for recalling in the "Nineteenth Century" for
the public mind in this connection from heated
to sober fact, I do not think a brief additional ex-
tion of Virchow's views, and of my relation to them,
e out of place here.

e keynote of his position is struck in the preface to
xcellent English translation of his lecture—a preface
n expressly by himself. "Nothing," he says, "was
r from his intention than any wish to disparage the
services rendered by Mr. Darwin to the advancement
logical science, of which no one has expressed more
ation than himself. On the other hand, it seemed
ime to him to enter an energetic protest against the
ots that are made to proclaim the problems of re-
as actual facts, and the opinions of scientists as

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established science." On the ground, a
it promotes the pernicious delusions
Virchow considers the theory of evoluti
his fidelity to truth is so great that h
danger and teach the theory, if it w
"However dangerous the state of thing
confederates be as mischievous as they
not hesitate to say that from the mon
become convinced that the evolution t
fectly established doctrine—so certain th
our oath to it, so sure that we could
from that moment we could not dare t
about introducing it into our actual lif
communicate it to every educated man
to every child, to make it the founda
ideas of the world, of society, and the
upon it our whole system of educatio
be a necessity."

It would be interesting to know the
by the pronoun "we" in the first sente
ing quotation. No doubt Professor Hae
this canon in all its fulness, and found
tion. He would say without hesitation

sing it upon the public at large. His "we," I su
ds definition. If he means that the theory of e
ought to be introduced into our schools, not
erts are agreed as to its truth, but when the com
y is prepared for its introduction, then, I think,
nt, and that, as a matter of social policy, Dr. Ha
ld be wrong in seeking to antedate the period of i
luction. In dealing with the community great cha
st have *timeliness* as well as truth upon their side.
he mouths of thinkers be stopped, the necessary s
paration will be impossible; an unwholesome div
l be established between the expert and the public,
slow and natural process of leavening the social
discovery and discussion will be displaced by s
g far less safe and salutary.

The burden, however, of this celebrated lecture
ning that a marked distinction ought to be made
en that which is experimentally proved, and that w
still in the region of speculation. As to the la
chow by no means imposes silence. He is far too
ous a man to commit himself, at the present tim
, to any such absurdity. But he insists that it ou
to be put on the same evidential level as the form

regard to the connection between phys
mental phenomena he says: "I will,
grant that we can find certain gradatio
points at which we trace a passage fron
to processes purely physical, or of a
Throughout this discourse I am not as
never be possible to bring psychical pr
mediate connection with those that are
say is that we have *at present* no right
sible connection as a *doctrine* of scien
paragraph he reiterates his position wit
introduction of such topics into scho
must draw," he says, "a strict distinc
we wish to *teach*, and what we wish t
objects of our research are expressed a
potheses). *We need not keep them to*
ready to communicate them to all the wor
is the problem; that is what we strive
vestigation of such problems, in which
may be interested, cannot be restricted
is Freedom of Inquiry. But the problem
not, without further debate, to be mad
will not concede to Dr. Haeckel "that
the schoolmasters to decide, whether the

men, I think we should be abusing our pow
be imperilling our power, unless in our te
strict ourselves to this perfectly safe and un
main. From this domain *we may make incu*
field of problems, and I am sure that every v
kind will then find all needful security and
have emphasized by italics two sentences in
series of quotations; the other italics are
own.

Virchow's position could not be made c
comments of mine than he has here mad
That position is one of the highest practica
"Throughout our whole German Fatherlan
"men are busied in renovating, extending,
ing the system of education, and in inventin
in which to mold it. On the threshold of o
stands the Prussian law of education. In al
States larger schools are being built, new ed
tablishments are set up, the universities a
'higher' and 'middle' schools are founded. I
the question, What is to be the chief subs
teaching?" What Virchow thinks it ought a
to be is disclosed by the foregoing quota

then, I have never advocated the int
theory of evolution into our schools.
disposed to resist its introduction before
been better understood and its utility
nized than it is now by the great body
The theory ought, I think, to bide its ti
conflict of discovery, argument, and opi
it this recognition. A necessary conditi
is that free discussion should not be pr
the ferocity of reviewers or the arm of t
as I said before, the work of social prep
on. On this count, then, I claim acquit
moment on the side of Virchow.

Besides the duties of the chair, wh
privileged to occupy in London for mo
of a century, and which never involve
part, *pro* or *con*, in reference to the th
I have had the honor of addressing a
pool, Belfast, and Birmingham; and in t
theory of evolution, and the connected
taneous generation, have been more or l
Let us now examine whether in my refe
parted from the views of Virchow or n

In the Liverpool discourse after stan

know something of our remotest ancestr
detachment from the sun, life, as we unde
not have been present on the earth. Ho
come there? The thing to be encouraged
ent freedom—a freedom preceded by the
which checks licentiousness in speculat
thing to be repressed, both in science an
dogmatism. And here I am in the hand
ing, willing to end, but ready to go on.
to intrude upon you unasked the unformed no
floating like clouds, or gathering to more soli
the modern speculative mind."

I then notice more especially the basis
"Those who hold the doctrine of evolut
means ignorant of the uncertainty of their
only yield to it a provisional assent. They r
ular hypothesis as probable; and, in the ut
any proof of the illegality of the act, the
method of nature from the present into th
the observed uniformity of nature is thei
Having determined the elements of their cu
of observation and experiment, they prolo
into an antecedent world, and accept as pro

nuity of nature, I cannot stop abruptly whe
scopes cease to be of use. At this point the
mind authoritatively supplements that of the
intellectual necessity I cross the boundary c
mental evidence, and discern in that 'matte
in our ignorance of its latent powers, and nc
our professed reverence for its Creator, have
ered with opprobrium, the promise and poter
restrial life." Without halting for a momer
do the precise thing which Professor Virche
be necessary. "If you ask me," I say, "
exists the least evidence to prove that any
can be developed out of matter independen
dent life, my reply is that evidence conside
conclusive by many has been adduced, and
to follow a common example, and accept
cause it falls in with our belief, we should
with the evidence referred to. But there i
man of science a desire stronger than the wis
beliefs upheld; namely, the desire to hav
And those to whom I refer as having studi
tion, believing the evidence offered in favor
ous generation' to be vitiated by error, can
They know full well that the chemist now

proof that life can be developed, save fro
antecedent life." *

Comparing the theory of evolution with
I thus express myself: "The basis of the
lution consists, not in an experimental de
the subject is hardly accessible to this mod
in its general harmony with scientific thoug
trast, moreover, it derives enormous relativ
the one side we have a theory, which conv
whose garment is seen in the visible unive
tificer, fashioned after the human model,
broken efforts, as man is seen to act. On
we have the conception that all we see aro
within us—the phenomena of physical nat
those of the human mind—have their uns
in a cosmical life, if I dare apply the ter
mal span of which is offered to the investig
Among thinking people, in my opinion, th
tion has a higher ethical value than that of
tificer. Be that as it may, I make here no
theory of evolution which can reasonably l

"Ten years have elapsed," said Dr. H
wich in 1868,* "since the publication of "

Italian edition. So far from Natural S
thing of the past [the 'Athenæum' had
so], it is an accepted doctrine with al
sophical naturalist, including, it will a
stood, a considerable proportion who are
admit that it accounts for all Mr. Darwi
In the following year, at Innsbruck, He
the same ground.' Another decade has
he is simply blind who cannot see the e
made by the theory during that time. S
ward and visible signs of this advance
cated. The hostility and fear which se
the recognition of Mr. Darwin by his ow
vanished, and this year Cambridge, ami
mation, conferred on him her Doctor
Academy of Sciences in Paris, which h
sistently closed its doors against Mr.
yielded at last; while sermons, lectures,
ticles plainly show that even the clergy
extent, become acclimatized to the Dar
brief reference to Mr. Darwin in the
dress was based upon the knowledge t
had been accomplished, and were still g

That the lecture of Professor Virchow

lessons of caution which he inculcates w
by me, years before his voice was heard u
has been proved in the foregoing pages. I
if he had preceded me instead of following
desire had been to incorporate his wishe
I could not have accomplished this more
is possible, moreover, to draw the coinc
further, for most of what he has said ab
generation might have been uttered by m
opinion that the theory of evolution in it
involves the passage from matter which
be inorganic into organized matter; in
volves the assumption that at some period
earth's history there occurred what would
"spontaneous generation." I agree with
proofs of it are still wanting." "Whoeve
calls to mind the lamentable failure of
made very recently to discover a decided
generatio æquivoca in the lower forms of
the inorganic to the organic world will fe
rious to demand that this theory, so utte
should be in any way accepted as the basis
of life." I hold with Virchow that the fai
lamentable, that the doctrine *is* utterly di
my position here is so well known that I

what I had said seventeen years previousl day Review." The Professor continues attraction and repulsion as exhibitions of cal phenomena, I simply throw the Psyche dow, and the Psycho ceases to be a Psych in passing, that the Psyche that *could* be window is not worth house-room. At this lator, who is evidently a man of culture, foot-note. "As an illustration of Prof meaning, we may quote the conclusion Tyndall arrives respecting the hypothesis offered as an explanation or a simplifica of obscure phenomena—psychical phenor them. 'If you are content to make yo rendering of a phenomenon which refu ordinary physical laws, I, for one, would exercise of ideality.'"[1] Professor Virch admit, required illustration; but I do not the quotation from me subserves this pu even know whether I am cited as meriti serving opprobrium. In a far coarser f ance of mine has been dealt with in othe therefore be worth while to spend a few w

The sting of a wasp at the finger-end

which, strictly interpreted, is atomic motion a case, propagated along the nerve, and com the brain. Again, on feeling the sting I fl violently away What has caused this motion The command from the brain to remove the along the motor nerves to the proper muscle force being unlocked, they perform the wor of them. But what moved the nerve mol unlocked the muscle? The sense of pain, i plied. But how can a sense of pain, or an of consciousness, make matter move? Not al pain or pleasure in the world could lift a st a billiard-ball; why should it stir a molecu express the motion numerically in terms of t and the difficulty immediately appears. He long ago entertained by philosophers, but la into special prominence, that the physical p complete in themselves, and would go on jus if consciousness were not at all implicated. ness, on this view, is a kind of by-product i in terms of force and motion, and unessential lecular changes going on in the brain.

Four years ago, I wrote thus: "Do states o ness enter as links into the chain of antecede quence, which gives rise to bodily actions? S

hold the automaton theory that states c
produced by the motion of the molecul
this production of consciousness by r
to me quite as unpresentable to the m
production of molecular motion by c
reject one result I must reject both
neither, and thus stand in the presenc
hensibles, instead of one Incomprehen
cede from the automaton theory, tho
friends who have all my esteem, and
avowal which occurs with such v
throughout the foregoing pages; nam
incapacity to grasp the problem.

This avowal is repeated with empl
to which Professor Virchow's translat
What, I there ask, is the causal conn
objective and the subjective—between
and states of consciousness? My answ
the connection, nor am I acquainted
does. It is no explanation to say tha
subjective are two sides of one and the
Why should the phenomenon have two
very core of the difficulty. There are

sentable. But we can form no picture of the pr
ereby consciousness emerges, either as a necessary
as an accidental by-product, of this series of act
reverse process of the production of motion by
usness is equally unpresentable to the mind. We
in fact on the boundary line of the intellect, w
ordinary canons of science fail to extricate us. I
true to these canons, we must deny to subjective
ena all influence on physical processes. The
nical philosopher, *as such*, will never place a stat
sciousness and a group of molecules in the rela
mover and moved. Observation proves them to i
but, in passing from the one to the other, we
blank which the logic of deduction is unable to
s, the reader will remember, is the conclusion at w
ad arrived more than twenty years ago. I lay
aringly the central difficulty of the materialist,
him that the facts of observation which he consi
simple are "almost as difficult to be seized ment
he idea of a soul." I go further, and say, in effect
e who wish to retain this idea, "If you abandon
rpretations of grosser minds, who image the soul
syche which could be thrown out of the window-

then I, for one, would not object to th
ity." I say it strongly, but with goo
theologian, or the defender of theolog
scourges me for putting the question in
of black ingratitude.

Notwithstanding the agreement thu
there are certain points in Professor V
which I should feel inclined to take
it was hardly necessary to associate th
tion with Socialism; it may be even
it was correct to do so. As Lange re
Socialism, or of its extreme leaders, i
existing systems of government, and a
them to this end is welcomed, whethe
papal infallibility. For long years
Church and State united against the
therefore regarded with a common hatr
does a serious difference arise between
than a portion of the Socialists begin i
with the former.[1] The experience of
elections illustrates Lange's position.
truer to my mind than this fear of p

usly undreamed of, which it offers of the enigma
and organization. He points to the clouds of
confusion which it has already dispersed, and s
the progress of discovery since its first enuncia
imply a record of the approach of the theory to
plete demonstration. One point in this "popu
osition deserves especial mention here. Helmh
rs to the dominant position acquired by German
siology and medicine, while other nations have
ast of her in the investigation of inorganic na
claims for German men the credit of pursuing
agging and self-denying industry, with purely
s, and without any immediate prospect of prac
ity, the cultivation of pure science. But that w
determined German superiority in the fields refe
was, in his opinion, something different from this.
ries into the nature of life are intimately conne
psychological and ethical questions; and he cl
his countrymen a greater fearlessness of the co
nces which a full knowledge of the truth may
y along with it, than reigns among the inquirer
r nations. And why is this the case? "England
nce," he says, "possess distinguished investigato

of half knowledge. A cheerfully labor
people—a people morally strong—can
truth full in the face. Nor are they t
enunciation of one-sided theories, eve
appear to threaten the bases of socie
of Helmholtz are, in my opinion, wise
cable to the condition of Germany at t
than those which express the fears of
It will be remembered that at the tim
chief anxieties were directed toward I
has since that time given ample evide
crush, not only Socialists, but anti-So
impose on her a yoke which she refuse

In close connection with these uttera
I place another utterance not less n
was understood and appreciated by the
addressed. "If," said the President o
ciation in his opening address in Dul
down beforehand the precise limits of
the problem of physical science wou
solved. But the question to which th
has often to address himself is, not m
able to solve this or that problem; bu

powers can resound. If, then, at a moment whe
himself placed on a pinnacle from which he is c
to take a perspective survey of the range of sci
to tell us what he can see from his vantage-gro
such a moment, after straining his gaze to the
of the horizon, and after describing the most di
well-defined objects, he should give utterance als
of the subjective impressions which he is consc
receiving from regions beyond; if he should de
abilities which seem opening to his view; if he sh
lain why he thinks this a mere blind alley and th
path; *then the fault and the loss would be alike*
refused to listen calmly, and temperately to form
judgment on what we hear; then assuredly it is we
be committing the error of confounding matters of
matters of opinion, if we failed to discriminate bet
various elements contained in such a discourse, and
that they had been all put on the same footing."

While largely agreeing with him I cannot quite acc
setting in which Professor Virchow places the c
dly abortive attempts to secure an experimental b
the doctrine of spontaneous generation. It is no
rine "so discredited" that some of the scientific thi

on, the planets were detached; and tha
is the residual nucleus of the flocculen
from which the planets were successively
as we define it, was not possible for e
this separation. When and how did it
already pressed this question, but have
swer.[1] If, with Professor Knight, we
account of the introduction of life upo
poem, not as a statement of fact, where
guidance as to the fact? There does n
possessing the strength of a cobweb to
pothesis which ascribes the appearance o
tency of matter" which finds expression
tion.[2] This hypothesis is not without i
they vanish when compared with those
its rivals. There are various facts in
connected, and whose connections we ar
but we do not think of filling the gap
the intrusion of a separable spiritual ag
ner, though we are unable to trace the
from the nebula, when there was no lif
the present earth where life abounds, th
tice of science pronounce against the in

creative hypothesis is less an assertion of knowl
n a protest against the assumption of knowledge w
st long, if not always, lie beyond us, and the clai
ch is a source of perpetual confusion." At the s
e, when I look with strenuous gaze into the w
blem as far as my capacities allow, overwhelming
is the predominant feeling. This wonder has con
from the ages just as much as my understanding,
has an equal right to satisfaction. Hence I say
ndoning your illegitimate claim to knowledge,
e, with Job, your forehead in the dust and ackn
e the authorship of this universe to be past fin
if, having made this confession, and relinquished
ws of the mechanical theologian, you desire, for the
ction of feelings which I admit to be, in great p
se of humanity at large, to give ideal form to
ver that moves all things—it is not by me that
find objections raised to this exercise of ideality
e only consciously and worthily carried out.

Again, I think Professor Virchow's position, in reg
the question of *contagium animatum* is not altoge
of true philosophy. He points to the antiquity
doctrine. "It is lost," he says, "in the darkness

differently to different minds. By some
missed with a sneer; to others they will
of genius on the part of those who
There are men, and by no means the
however wealthy in regard to facts, can
the region of principles; and they are s
ant of those who can. They are formed
ously on the lower levels of thought, u
pinions necessary to reach the heights.
ize the mental act—the act of inspiration
called—by which a man of genius, afte
and proving, reaches a theoretic conceptio
and illuminates the tangle of centuries o
experiment. There are minds, it may be
who at the present moment stand in thi
Darwin. For my part, I should be incli
penetration rather than to presumption
contagium animatum. He who invented
I think, to be held in esteem; for he ha
quantity of fact, and the measure of an
justify a man of genuis in taking a step
ertheless," says Professor Virchow, "n
throughout a long time to discover th
of disease. The sixteenth century did n

like the undulatory theory, has been a motive p
not an anodyne. "At last," continues Profe
chow, "in the nineteenth century we have begun
by little really to find *contagia animata*." So m
more honor, I infer, is due to those who, three c
s in advance, so put together the facts and analo
contagious disease as to divine its root and chara
fessor Virchow seems to deprecate the "obstina
which this notion of a *contagium vivum* emer
e I should not be inclined to follow him; becau
not know, nor does he tell me, how much the dis
of facts in the nineteenth century is indebted to
mulus derived from the theoretic discussions of pre
centuries. The genesis of scientific ideas is a sub
profound interest and importance. He would be l
r philosopher who would sever modern chemistry f
efforts of the alchemists, who would detach mod
nic doctrines from the speculations of Lucretius
predecessors, or who would claim for our pre
wledge of contagia an origin altogether independ
e efforts of our "forefathers" to penetrate this enig

Finally, I do not know that I should agree with I

of growth; and had they to speak of th
they would be able to announce an enor
ing of the theoretic fibre. Fissures in
then existed, and which left little hop
spanned, have been since filled in, so
the theory is tested the more fully de
with progressive experience and discov
probably never fill all the gaps; but th
vent a profound belief in the truth of
taking root in the general mind. Much l
a total denial of the theory. The man o
sumes in such a case the position of a
be stranded and isolated. The proper
opinion, is to give to the theory during
growth as nearly as possible a *proportion*
if it be a theory which influences practic
to follow its probable suggestions where
ability is for the moment unattainable.
the theory of *contagium vivum* more
mind, and must regret the attitude of de
Professor Virchow toward that theory.
friend Klebs to pardon me," he says, "
ing the late advances made by the doct
fungi I still persist in my reserve as far

to be discovered, it is your bounden duty
it," I should cordially agree with him. Bu
reserved denial he quenches the light of prob
ought to guide the practice of the medical
here and in relation to the theory of evo
upon one side has begotten excess upon the

NOTE.—As might have been expected, Professor Vircho
in practice far too sound a philosopher to be restricted by the
in his critique of Dr. Haeckel. In his recent discourse upon t
and answers the question, "What is the contagium?" in the
"Et qu'est ce que le contagium? A mon avis, l'analogie de
charbon contagieux me paraît si grande qu'il me semble p
un organisme microscopique qui contient le germe de l'affe
qu'à présent on a peu cherché à trouver cet organisme."
tifique," March, 1879.

XVI

THE ELECTRIC LIGHT[1]

THE subject of this evening's discourse
by our late honorary secretary.[2] Th
has for me its own connotations.
among other things, the loss of a comrade
I have worked for thirteen years. On the
gret is not without its opposite in the feeli
I have seen him rise by sheer intrinsic me
intellectual, to the highest official position
the power of English science to bestow. W
constant desire and practice were to promot
and extend the usefulness of this Institutio
at a time when the electric light occupie
public attention, a few sound notions regar
more purely scientific side, might, to use
expression, be "planted" in the public min

, repeating Volta's experiments, and extending them ny ways. The light and heat of the voltaic circuit cted marked attention, and in the innumerable tests ls to which this question was subjected, the utility tinum and charcoal as means of exalting the light all hands recognized. Mr. Children, with a bat passing in strength all its predecessors, fused plati es eighteen inches long, while "points of charcoal ced a light so vivid that the sunshine, compared appeared feeble."[1] Such effects reached their cu ion when, in 1808, through the liberality of a few m s of the Royal Institution, Davy was enabled to uct a battery of two thousand pairs of plates, ich he afterward obtained calorific and luminous ef transcending anything previously observed. The flame between the carbon terminals was four in g, and by its heat quartz, sapphire, magnesia, e, were melted like wax in a candle flame; w gments of diamond and plumbago rapidly disappea if reduced to vapor.[2]

The first condition to be fulfilled in the developm heat and light by the electric current is that it s ounter and overcome resistance. Flowing throug fect conductor, no matter what the strength of the

A rod of unresisting copper carries awa
unwarmed an atmospheric discharge com
to splinter a resisting oak. I send the s
through a wire composed of alternate li
and platinum. The silver offers little resi
num offers much. The consequence is th
is raised to a white heat, while the silve
warmed. The same holds good with rega
terminals employed for the production
light. The interval between them offers
sistance to the passage of the current, a
gathering up of the force necessary to l
interval that the voltaic current is able t
bon into that state of violent intestine co
we call heat, and to which its effulgen
small interval of air usually suffices to
But when the carbon points are first broug
then separated, there occurs between the
incandescent matter which carries, or may
rent over a considerable space. The lig
wholly from the incandescent carbons. Th
them is filled with a blue flame which, be
by the earth's magnetism, receives the ma

For seventy years, then, we have been
of this transcendent light without applying
mination of our streets and houses. Such
suggested themselves at the outset, but ther
difficulties in their way. The first difficult
the waste of the carbons, which are dissipate
ordinary combustion, and in part by the ele
of matter from the one carbon to the other.
carbons at the proper distance asunder re
devised, the earliest, I believe, by Staite, a
successful by Duboscq, Foucault, and Serri
been succeeded by Holmes, Siemens, Brov
Gramme, Lontin, and others. By such arra
first difficulty was practically overcome; but
graver one, is probably inseparable from the
of the voltaic battery. It arises from the
that inexorable law which throughout the
verse demands an eye for an eye, and a tooth
refusing to yield the faintest glow of heat o
light without the expenditure of an absolutely
tity of some other power. Hence, in practice
bility of any transformation must depend up
of the product in relation to that of the pow

warm the air. The zinc burns at the focu
flame, and we could readily determine the
generated by its combustion. But zinc can
only in air, but in liquids. It is thus bur
ulated water is poured over it; it is also
the voltaic battery. Here, however, to o
gen necessary for its combustion, the zinc
the hydrogen with which the oxygen is c
consequence is that the heat due to the
the metal in the liquid falls short of that
its combustion in air, by the exact quanti
separate the oxygen from the hydrogen. F
of the total heat are used up in this molec
one-fifth remaining to warm the battery.
residue that we must now fix our attention,
out of it that we manufacture our electric

Before you are two small voltaic batter
each. The two ends of one of them are ur
copper wire, while into the circuit of th
platinum wire is introduced. The platinum
white heat, while the copper wire is not sc
Now an ounce of zinc, like an ounce of
by its complete combustion in air a const

side. One of the fundamental truths to be l
is that the sum of the foreign and domesti
ternal and internal—heats is fixed and invari
to have heat outside, you must draw upon
in. These remarks apply to the electric li
intermediation of the electric current the mo
of the battery is not only carried away, but
so as to produce, at any distance from its
next in order to that of the sun. The
therefore be defined as the swift carrier of
ing itself here with invisible power, by a pr
mutation which outstrips the dreams of the
can discharge its load, in the fraction of a se
and heat, at the opposite side of the world.

Thus, the light and heat produced outsid
are derived from the metallic fuel burned w
tery; and, as zinc happens to be an expensiv
we have possessed the electric light for m
enty years, it has been too costly to come
use. But within these walls, in the autumn
day discovered a new source of electricity, w
now to investigate. On the table before me
covered copper wire, with its ends disunited
side of the coil from the table, and in doing
muscular effort necessary to overcome the s

mained separate, had no circuit through
pass. The current here evoked subsides
heat; this heat being the exact equivalen
of effort just referred to as over and abov
to overcome the simple weight of the c
coil is liberated it falls back to the tabl
ends are united it encounters a resistance
that of the air. It generates an electric
in direction to the first, and reaches the
minished shock. The amount of the din
rately represented by the warmth which
current develops in the coil. Various d
ployed to exalt these induced currents, a
instruments of Pixii, Clarke, and Saxton
spicuous. Faraday, indeed, foresaw tha
were sure to be made; but he chose to le
hands of the mechanician, while he hims
deeper study of facts and principles. "I
writes in 1831, "been desirous of discov
and new relations dependent on magnet
tion, than of exalting the force of those
being assured that the latter would find
opment hereafter."

decomposition of water by a powerful magneto-ele
chine constructed by M. Nollet, the oxygen and
gen necessary for the lime light. The experi
d, but the apparatus by which it was attempted
ed to Mr. Holmes other and more hopeful app
s. Abandoning the attempt to produce the lime l
persevering skill Holmes continued to improve
aratus and to augment its power, until it was fi
to yield a magneto-electric light comparable to
the voltaic battery. Judged by later knowledge,
machine would be considered cumbrous and defe
the extreme; but judged by the light of antece
nts, it marked a great step forward.

Faraday was profoundly interested in the growth of
discovery. The Elder Brethren of the Trinity H
had the wisdom to make him their "Scientific
r"; and it is interesting to notice in his reports reg
the light, the mixture of enthusiasm and caution w
racterized him. Enthusiasm was with him a mo
er, guided and controlled by a disciplined judgm
rode it as a charger, holding it in by a strong r
ile dealing with Holmes, he states the case of the li
and *con*. He checks the ardor of the inventor, a
regards cost, rejecting sanguine estimates, he ins

house, and apparently three or four times
horizontal plane in which they chiefly
made all above or below it black. The t
the churches, and the houses illuminated
ing in their effect upon the eye." Furth
port he expresses himself thus: "In fu
part of my duty, I beg to state that, in n
fessor Holmes has practically established
sufficiency of the magneto-electric light for
poses, so far as its nature and managemen
The light produced is powerful beyond a
have yet seen so applied, and in princip
mulated to any degree; its regularity i
great; its management easy, and its ca
confided to attentive keepers of the ord
intellect and knowledge." Finally, as r
duct of Professor Holmes during these m
ments, it is only fair to add the follow
which Faraday closes the report submitt
Brethren of the Trinity House on the 29t
"I must bear my testimony," he says,
openness, candor, and honor of Profess
has answered every question, concealed
explained every applied principle, given
a change either in this or that direction

se had the intelligent courage to establish the
nes of Holmes permanently at Dungeness, where
gneto electric light continued to shine for many y
The magneto-electric machine of the Alliance Comp
succeeded to that of Holmes, being in various
ery marked improvement on the latter. Its curr
e stronger and its light was brighter than those o
decessor. In it, moreover, the commutator, the f
and destruction of which were sources of irregul
deterioration in the machine of Holmes, was, at
gestion of M. Masson,[1] entirely abandoned; alte
currents instead of the direct current being emplo
Serrin modified his excellent lamp with the exp
w of enabling it to cope with alternating curr
ring the International Exhibition of 1862, where
chine was shown, M. Berlioz offered to dispose of
ention to the Elder Brethren of the Trinity Ho
y referred the matter to Faraday, and he replie
ows: "I am not aware that the Trinity House auth
have advanced so far as to be able to decide whe
y will require more magneto-electric machines,
ther, if they should require them, they see reaso
pose the means of their supply in this country, f

Trinity House, determined to have the
apparatus, decided, in 1868, on the intro
chines on the Alliance principle into the
Souter Point and the South Foreland.
were constructed by Professor Holmes, and
tinue in operation. With regard, then, to
of electricity to lighthouse purposes, the
was this: The Dungeness light was introdu
31, 1862; the light at La Hève on Decem
nearly two years later. But Faraday's ex
at the South Foreland preceded the lighti
by more than two years. The electric ligh
established at Cape Grisnez. The light
Souter Point on January 11, 1871; and at
land on January 1, 1872. At the Lizard, w
newest and most powerful development
light, it began to shine on January 1, 18

I have now to revert to a point of
moment, but which really constitutes an
in the development of this subject. I re
given in 1857 to the rotating armature
Siemens, of Berlin. Instead of employi

er, and between their poles a Siemens armature.
ends of the wire which surrounds the armature
disconnected. In turning the handle and ca
armature to rotate, I simply overcome ordinary
nical friction. But the two ends of the armature
be united in a moment, and when this is done I i
ely experience a greatly increased resistance to
. Something over and above the ordinary frictio
machine is now to be overcome, and by the exp
of an additional amount of muscular force I am
overcome it. The excess of labor thus thrown
arm has its exact equivalent in the electric cur
erated, and the heat produced by their subsidenc
coil of the armature. A portion of this heat ma
dered visible by connecting the two ends of the
a thin platinum wire. When the handle of the
ne is rapidly turned the wire glows, first with a
, then with a white heat, and finally with the hea
on. The moment the wire melts, the circuit round
ature is broken, an instant relief from the labor thr
n the arm being the consequence. Clearly realize
valent of the heat here developed. During the pe
urning the machine a certain amount of combust

between the voltaic battery and its gene electric current is to all intents and pu which transports the heat both of muscle any distance from the hearth where the f Not only is the current a messenger, but tensifier of magical power. The tempera is, in round numbers, 100° Fahr., and it i fication of this heat that one of the most r als, which requires a heat of 3,600° Fah been reduced to the molten condition.

Zinc, as I have said, is a fuel far too e mit of the electric light produced by its c used for the common purposes of life, and perceive that the human muscles, or ever a horse, would be more expensive still. we can employ the force of burning coal chine, and it is this employment of ou rendered possible by Faraday's discover out to us the prospect of being able to a light to public use.

In 1866 a great step in the intensific currents, and the consequent augmentation electric light, was taken by Mr. Henry W

ture currents were obtained vastly stronger than t
nerated by the small magneto-electric machine. T
rents might have been immediately employed to
e the electric light; but instead of this they
nducted round a second electro-magnet of vast
ween whose poles rotated a Siemens armature of
ponding dimensions. Three armatures therefore wer
ved in this series of operations: first, the armatur
small magneto-electric machine; secondly, the a
of the first electro-magnet, which was of consider
; and, thirdly, the armature of the second electro-
which was of vast dimensions. With the curr
wn from this third armature, Mr. Wilde obtained
s, both as regards heat and light, enormously
ding those previously known.'

But the discovery which, above all others, brought
ctical question to the front is now to be conside
the 4th of February, 1867, a paper was received
Royal Society from Dr. William Siemens bearing
, "On the Conversion of Dynamic into Electrical F
out the use of Permanent Magnetism."* On the

* Mr. Wilde's paper is published in the "Philosophical Transactions"

of February a paper from Sir Charles W
ceived, bearing the title, "On the Augm
Power of a Magnet by the reaction the
induced by the Magnet itself." Both pa
with the same discovery, and which we
experiments, were read upon the same
14th of February. It would be difficul
whole field of science a more beautiful ex
teraction of natural forces than that set f
papers. You can hardly find a bit o
hardly pick up an old horseshoe, for exa
not possess a trace of permanent magn
such a small beginning Siemens and W
taught us to rise by a series of interactio
net and armature to a magnetic intensity
approached. Conceive the Siemens arm
tween the poles of a suitable electro-m
this latter to possess at starting the faint
netism; when the armature rotates, curre
mal strength are generated in its coil.
that coil be connected with the wire
electro-magnet. The infinitesimal curre
the armature will then circulate round t

y this play of mutual give and take between mag
nd armature, the strength of the former is raised i
ery brief interval from almost nothing to complete m
etic saturation. Such a magnet and armature are abl
roduce currents of extraordinary power, and if an e
ic lamp be introduced into the common circuit of m
et and armature, we can readily obtain a most power
ght.[1] By this discovery, then, we are enabled to av
e trouble and expense involved in the employment
rmanent magnets; we are also enabled to drop the
ing magneto-electric machine, and the duplication of
ectro-magnets. By it, in short, the electric generator
far simplified, and reduced in cost, as to enable el
city to enter the lists as the rival of our present mea
illumination.

Soon after the announcement of their discovery
emens and Wheatstone, Mr. Holmes, at the instance
e Elder Brethren of the Trinity House, endeavored
rn this discovery to account for lighthouse purpos
ready, in the spring of 1869, he had constructed
chine which, though hampered with defects, exhibit
traordinary power. The light was developed in t
us of a dioptric apparatus placed on the Trinity Wha

of Holmes, however, was rapidly distance
and more powerful machines of Siemens a

As regards lighthouse illumination, the
ward was taken by the Elder Brethren
House in 1876–77. Having previously c
establishment of the electric light at the
wall, they instituted, at the time referred
series of comparative experiments wherei
of Holmes, of the Alliance Company, of
Gramme, were pitted against each other.
and the Gramme machines delivered direc
those of Holmes and the Alliance Compa
ternating currents. The light of the lat
same intensity in all azimuths; that of
different in different azimuths, the dischar
ulated as to yield a gush of light of spe
one direction. The following table gives
dles the performance of the respective ma

Name of Machine	Maximu
Holmes	1,523
Alliance	1,953
Gramme (No. 1)	6,663
Gramme (No. 2)	6,663
Siemens (Large)	14,818
Siemens (Small, No. 1) . . .	5,539

These determinations were made with extreme care
curacy by Mr. Douglass, the engineer-in-chief, and
rес, the assistant engineer of the Trinity House. I
actically impossible to compare photometrically and
tly the flame of the candle with these sun-like lig
light of intermediate intensity—that of the six-w
inity oil lamp—was therefore in the first instance c
red with the electric light. The candle power of the
up being afterward determined, the intensity of the e
light became known. The numbers given in the ta
ove the superiority of the Alliance machine over
Holmes. They prove the great superiority both of
amme machine and of the small Siemens machine
Alliance. The large Siemens machine is shown
ld a light far exceeding all the others, while the co
g of two Grammes, or of two Siemens together,
ected for the first time, was followed by a very g
gmentation of the light, rising in the one case f
63 candles to 11,396, and in the other case from 6
ndles to 14,134. Where the arc is single and the
rnal resistance small, great advantages attach to
mmens light.

After this contest, which was conducted throughou
most amicable manner, Siemens machines of type

Jablochkoff candles on the Thames Emban
the Holborn Viaduct, delivers four currents
through its own circuit. In each circuit a
through which the current belonging to the
in succession. The lights correspond to so
ing spaces, over which, as already explaine
has to leap; the force which accomplishes
that which produces the light. Whether th
be competent to pass through five lamps in
to sustain only a single lamp, depends ent
will and skill of the maker of the machin
guide him, definite laws laid down by Ohm
ago, by which he must abide.

Ohm has taught us how to arrange the
Voltaic battery so as to augment indefinit
motive force—that force, namely, which urg
forward and enables it to surmount exte
We have only to link the cells together so
rent generated by each cell shall pass th
others, and add its electro-motive force t
the others. We increase, it is true, at the
resistance of the battery, diminishing there
ty of the current from each cell, but we augm
of the integrated current to overcome extern
The resistance of the battery itself may i

the use of thin wires, the convolutions of the rota
mature as, a moment ago, we augmented the cells of
ltaic battery. Each additional convolution, like e
ditional cell, adds its electro-motive force to that of
e others; and though it also adds its resistance, ther
minishing the quantity of current contributed by e
nvolution, the integrated current becomes endowed w
e power of leaping across the successive spaces ne
ry for the production of a series of lights in its cou
e current is, as it were, rendered at once thinner
ore piercing by the simultaneous addition of internal
stance and electro-motive power. The machines, on
er hand, which produce only a single light hav
all internal resistance associated with a small elec
tive force. In such machines the wire of the rotat
mature is comparatively short and thick, copper rib
stead of wire being commonly employed. Such
nes deliver a large quantity of electricity of low t
n in other words, of low leaping power. Hen
ough competent, when their power is converged u
ingle interval, to produce one splendid light, their c
nts are unable to force a passage when the number
ervals is increased. Thus, by augmenting the con
tions of our machines we sacrifice quantity and g

we want to obtain in the same circuit sev
moderate intensity, machines of high inter
and of correspondingly high electro-motive
be invoked.

When a coil of covered wire surrounds
the two ends of the coil being connected t
alteration of the magnetism of the bar is ac
the development of an induced current in t
current is only excited during the period
change. No matter how strong or how weal
ism of the bar may be, as long as its cond
permanent no current is developed. Concei
pole of a magnet placed near one end of
moved along it toward the other end. Du
of the pole's motion there will be an incess
the magnetism of the bar, and accompanyin
we shall have an induced current in the sur
If, instead of moving the magnet, we move
its surrounding coil past the magnetic pole,
teration of the magnetism of the bar will
similar current will be induced in the coil
here the fundamental conception which led
to the construction of his beautiful machine
at giving continuous motion to such a bar

coil surrounding the ring flowed in opposite directio
t it was easy, by the mechanical arrangement calle
nmutator, to gather up the currents and cause them
w in the same direction. The first machines of Gramm
erefore, furnished *direct* currents, similar to those yiel
the voltaic pile. M. Gramme subsequently so modi
machine as to produce alternating currents. Such
rnating machines are employed to produce the lig
w exhibited on the Holborn Viaduct and the Tha
nbankment.

Another machine of great alleged merit is that of
ntin. It resembles in shape a toothed iron wheel,
th being used as cores, round which are wound coils
pper wire. The wheel is caused to rotate between
posite poles of powerful electro-magnets. On pass
h pole the core or tooth is strongly magnetized,
stantly evokes in its surrounding coil an induced c
nt of corresponding strength. The currents excited
proaching to and retreating from a pole, and in pass
fferent poles, move in opposite directions, but by me
a commutator these conflicting electric streams are ga
ed up and caused to flow in a common bed. The b
ns, in which the currents are induced, can be so
eased in number as to augment indefinitely the powe

The Farmer-Wallace machine is also an
great power. It consists of a combination o
induced currents, and of inducing electro
latter being excited by the method discovere
and Wheatstone. In the machines intende
duction of the electric light, the electro-mot
great as to permit of the introduction of se
the same circuit. A peculiarly novel feature
Wallace system is the shape of the carbon
rods, two large plates of carbons with beve
employed, one above the other. The ele
passes from edge to edge, and shifts its posi
as the carbon is dissipated. The duration o
this case far exceeds that obtainable with
myself seen four of these lights in the sa
Mr. Ladd's workshop in the City, and the
believe, employed at the Liverpool Stre
the Metropolitan Railway. The Farmer-W
tity machine" pours forth a flood of elec
tension. It is unable to cross the inter
for the production of the electric light, b
thick copper wires. When sent through
of iridium, this refractory metal emits a lig
dinary splendor.[1]

Using the magnets of the Alliance Company disposition of his bobbins, M. de Méritens eight magnets a light equal to that produ magnets in the Alliance machines. Whi occupied is only one-fifth, the cost is litt one-fourth of the latter. In the De Méri the commutator is abolished. The internal sensible, and the absorption of power, in r effects produced, is small. With his larger de Méritens maintains a considerable num in the same circuit.'

In relation to this subject, inventors classes, the contrivers of regulators and th of machines. M. Rapieff has hitherto belon tors of the first class, but I have reason to is engaged on a machine which, when compl him in the other class also. Instead of two rods, M. Rapieff employs two pairs of ro forming a V. The light is produced at the tion of the four carbons. The device for light is of the simplest character. At the stand which supports the carbons are two magnets. One of them, when the current

Through the liberality of the prop "Times," every facility has been given to develop and simplify his invention at Square. The illumination of the press-had the pleasure of witnessing, under t M. Rapieff himself, is extremely effectual to the eye. There are, I believe, five same circuit, and the regulators are so the extinction of any lamp does not c action of the others. M. Rapieff has lately regulator.

Many other inventors might here be m ones are daily crowding in. Mr. Werder long known in connection with this subje as negative carbon a disk, and as positive he has, I am assured, obtained very satis The small resistances brought into play by enable Mr. Werdermann to introduce a n into a circuit traversed by a current of electro-motive power. M. Reynier is also a very beautiful little lamp, in which the carbon rod, properly adjusted, is caused to cumference of a carbon wheel which rota the point. The light is developed at the p

of copper, and by ingeniously discharging a
cold water against the interior of the cone.
copper is thus caused to remain fixed in sp
not dissipated, the positive carbon only nee
I have seen this lamp in action, and can be
its success.

I might go on to other inventions, achi
jected. Indeed, there is something bewild
recent rush of constructive talent into this d
plied electricity. The question and its prosp
ified from day to day, a steady advance
toward the improvement both of machines ar
With regard to our public lighting, I strongl
opinion that the electric light will at no dis
umph over gas. I am not so sure that it v
our private houses. As, however, I am anxi
dropping a word here that could influenc
market in the slightest degree, I limit my
general statement of opinion.

To one inventor in particular belongs the
idea, and the realization of the idea, of caus
bon rods to burn away like a candle. It is
say that I here refer to the young Russiar
Jablochkoff. He sets two carbon rods uprigh

substance between them melts like the wax c
The comparison, however, only holds good for
melting; for, as regards the current, the insula
is practically inert. Indeed, as proved by M.
Mr. Wilde, the plaster may be dispensed with
the current passing from point to point between
carbons.

M. de Méritens has recently brought out
dle, in which the plaster is abandoned, whi
the two principal carbons is placed a third in
of the same material. With the small De M
chine two of these candles can be lighted
they produce a very brilliant light.[1] In the
candle it is necessary that the carbons should b
at the same rate. Hence the necessity for alter
rents by which this equal consumption is secur
be seen that M. Jablochkoff has abolished regu
gether, introducing the candle principle in their
my judgment, the performance of the Jabloch
on the Thames Embankment and the Holborn
highly creditable, notwithstanding a considerab
light toward the sky. The Jablochkoff lam
be added, would be more effective in a st
their light would be scattered abroad by th

proposed constructor, and to talk the ma
him. The study of the inventor's mind wh
opened out was always of the highest inte
particularly well remember the impression
on such occasions by the late Mr. Darker,
instrument maker in Lambeth. This ma
struggle, and the reason of it was not fa
matter how commercially lucrative the wo
he was engaged might be, he would insta
from it to seize and realize the ideas of a
He had an inventor's power, and an inven
its exercise. The late Mr. Becker posse
power in a very considerable degree. On
Froment, Breguet, Sauerwald, and others
tioned as eminent instances of ability of th
minds resemble a liquid on the point of
Stirred by a hint, crystals of constructive
diately shoot through them. That Mr. E
this intuitive power in no common measur
what he has already accomplished. He h
tion to seize the relationship of facts and
the art to reduce them to novel and co
tions. Hence, though he has thus far acc
ing that we can recognize as new in relati

heat. From one end of a voltaic battery
dividing at a certain point into two branch
unite in a single wire connected with the oth
battery. From the positive end of the batte
passes first through the single wire to the
tion, where it divides itself between the bra
ing to a well-known law. If the branches
sistant, the current divides itself equally b
If one branch be less resistant than the oth
half the current will choose the freer path
law is that the quantity of current is inversel
to the resistance. A clear image of the proc
from the deportment of water. When a ri
island it divides, passing right and left of
and afterward reuniting. If the two branch
in depth, width, and inclination, the water
self equally between them. If they be unequ
quantity of water will flow through the more
And, as in the case of the water, we may
definite number of islands, producing an i
division of the trunk stream, so in the cas
ity we may have, instead of two branches,
of branches, the current dividing itself am
accordance with the law which fixes the re

unconnected with the water-pipes, the cir
plete and no current will flow; but if an
main, however distant from the battery, be
the adjacent water-pipes, the circuit will be
the current will flow. Supposing our bat
Charing Cross, and our rod of copper to be
site Somerset House, a wire can be carried
into the building, and the current passing
wire may be subdivided into any number
branches, which reunite afterward and retur
water pipes to the battery. The branch cu
employed to raise to vivid incandescence
metal like iridium or one of its alloys. In
tapped at one point, our main may be tappe
dred points. The current will divide in str
with law, its power to produce light being
by its strength. The process of division clo
the circulation of the blood; the electric
the outgoing current representing a great art
pipes carrying the return current representin
while the intermediate branches represent th
sels by which the blood is distributed throug
This, if I understand aright, is Mr. Ediso
mode of illumination. The electric force

the intricacy of the practical problem, I sh
prefer seeing it in Mr. Edison's hands to
mine.[1]

It is sometimes stated as a recommendati
tric light that it is light without heat; b
this it is only necessary to point to the
Davy, which show that the heat of the vo
scends that of any other terrestrial source.
from the carbon points is capable of acc
To simplify the subject, we will take the c
num wire at first slightly warmed by the cu
gradually raised to a white heat. When fi
wire sends forth rays which have no powe
nerve. They are what we call invisible ray
til the temperature of the wire has reached
Fahr. does it begin to glow with a faint, r
rays which it emits prior to redness are all
which can warm the hand but cannot excite
the temperature of the wire is raised to w
dark rays not only persist, but they are e
mented in intensity. They constitute about
the total radiation from the white-hot platinu
make up nearly 90 per cent of the emission
electric light. You can by no means have t
carbons without this invisible emission as
ment. The visible radiation is, as it were,

augment in power. The transparency of th
gases and metalloids—of oxygen, hydrog
chlorine, iodine, bromine, sulphur, phosphor
of carbon, for the invisible heat rays is e
Dissolved in a proper vehicle, iodine cuts th
diation sharply off, but allows the invisible
sion. By dissolving iodine in sulphur, Pro
has recently added to the number of our
filters. The mixture may be made as black
the visible, while remaining transparent for
rays. By such filters it is possible to detach
rays from the total radiation, and to watch t
tation as the light increases. Expressing
from a platinum wire when it first feels
touch—when, therefore, all its rays are invi
number 1, the invisible radiation from th
raised to a white heat may be 500 or more
then, by the diminution or transformation
luminous emission that we obtain the lumino
rays maintain their ground as the necessary
and companions of the light rays. When
concentrated, these powerful heat rays can pr
effects ascribed to the mirrors of Archimedes
of Syracuse. While incompetent to produce

In this way the dark rays emitted by the carbons are converted into light rays of all so powerless are these invisible rays to excit the eye has been placed at a focus compe platinum foil to bright redness, without expe visual impression. Light for light, no doubt of heat imparted by the incandescent carbons far less than that imparted by gas flames. I cause of the smaller size of the carbons, and parative smallness of the quantity of fuel c given time. It is also less because the air trate the carbons as it penetrates a flame. ture of the flame is lowered by the admixt which constitutes four-fifths of our atmospher while it appropriates and diffuses the heat, in the combustion; and this lowering of the te the inert atmospheric nitrogen renders necess bustion of a greater amount of gas to produ sary light. In fact, though the statement paradoxical, it is entirely because of its enc temperature that the electric light seems so this temperature that renders the proportion to non-luminous heat greater in the electric our brightest flames. The electric light, a

n, whose object is mainly industrial. It would be e
l probably in many cases true, to say that the
nts to gain knowledge, while the other wishes to m
oney; but I am persuaded that the mechanician not
quently merges the hope of profit in the love of
rk. Members of each of these classes are someti
ornful toward those of the other. There is, for ex
, something superb in the disdain with which Cu
nds over the discoveries of pure science to those
ply them: "Your grand practical achievements are o
easy application of truths not sought with a pract
ent truths which their discoverers pursued for th
n sake, impelled solely by an ardor for knowled
ose who turned them into practice could not have
ered them, while those who discovered them
ther the time nor the inclination to pursue them
practical result. Your rising workshops, your peop
onies, your vessels which furrow the seas; this ab
nce, this luxury, this tumult"—"this commotion,"
uld have added, were he now alive, "regarding
ctric light"—"all come from discoverers in Scien
ough all remain strange to them. The day that a
very enters the market they abandon it; it conce
m no more."

a nation to bear in mind that those practical
which strike the public eye, and excite publi
are the outgrowth of long antecedent labors
tinued, and ended, under the operation of a
lectual stimulus. "Few," says Pasteur, "seen
hend the real origin of the marvels of indu
wealth of nations. I need no other proof of
frequent employment in lectures, speeches an
guage of the erroneous expression, 'applied
statesman of the greatest talent stated some
in our day the reign of theoretic science had ri
place to that of applied science. Nothing,
say, could be more dangerous, even to practi
the consequences which might flow from
They show the imperious necessity of a r
higher education. There exists no category
which the name of 'applied science' could be
have science and the applications of scien
united as tree and fruit."

A final reflection is here suggested. We
us a small cohort of social regenerators—
thoughts and aspirations—who would place t
of the scientific mind under the control of
which should dictate to the man of scienc

tially ideal. Faraday lived in this ideal world. Nea lf a century ago, when he first obtained a spark fr magnet, an Oxford don expressed regret that such covery should have been made, as it placed a new a ble implement in the hands of the incendiary. To t, a Comtist hierarchy would have probably ado ression, sending Faraday back to his bookbinde ch as a more dignified and practical sphere of act an peddling with a magnet. And yet it is Farada ark which now shines upon our coasts, and promises uminate our streets, halls, quays, squares, warehous l, perhaps at no distant day, our homes.

END OF VOL. II. OF "FRAGMENTS OF SCIENCE"